1986

Automated aircraft static structural testing with computer aided interpretation.

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AUTOMATED AIRCRAFT STATIC STRUCTURAL
TESTING WITH COMPUTER
AIDED INTERPRETATION

by

James J. Miller

September 1986

Thesis Advisor: E. M. Wu

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY 2b DECLASSIFICATION / DOWNGRADING SCHEDULE	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School — 6b OFFICE SYMBOL (If applicable) 67	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000	7b. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000
8a NAME OF FUNDING / SPONSORING ORGANIZATION — 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
AUTOMATED AIRCRAFT STATIC STRUCTURAL TESTING WITH COMPUTER AIDED INTERPRETATION

12 PERSONAL AUTHOR(S)
Miller, James J.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Master's Thesis	FROM ______ TO ______	1986 September	83

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Aircraft Static Structural Test Computer Controlled Instrumentation

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The objective of this study is to improve three primary aspects of static structural testing at the Naval Postgraduate School. First, computer controlled digital multimeters simultaneously display twelve data locations on the structure while the test is in progress. Second, immediate interaction is permitted. If some unexpected data occurs during the testing, the test plan can be modified to focus in on any area of interest. Third, the operator is presented with two different real-time visual interpretations of the strain gage data reduced to the strain tensor components with animated deformations.

These objectives contribute to enhancing the real-time correlation between input load and output structural response in terms

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL E. M. Wu	22b TELEPHONE (Include Area Code) (408) 646-3459 — 22c OFFICE SYMBOL 67W

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. (Continued)

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Automated Aircraft Static Structural Testing With Computer Aided Interpretation

by

James John Miller
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1974

Submitted in partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
September 1986

ABSTRACT

The objective of this study is to improve three primary aspects of static structural testing at the Naval Postgraduate School. First, computer controlled digital multimeters simultaneously display twelve data locations on the structure while the test is in progress. Second, immediate interaction is permitted. If some unexpected data occurs during the testing, the test plan can be modified to focus in on any area of interest. Third, the operator is presented with two different real-time visual interpretations of the strain gage data reduced to the strain tensor components with animated deformations.

These objectives contribute to enhancing the real-time correlation between input load and output structural response in terms of direct physical measurements rather than indirect abstract tensor components.

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENT

My sincerest thanks to my wife Eloise and son William who's ever-present quiet support made this project feasible. Special thanks to Mr. Ted Dutton who contributed expert technical assistance, friendship and a sense of humor. And thanks to Professor Ed Wu, who had faith enough in my abilities to allow me to pursue a area of study which is not directly within his realm of interest. He provided just enough guidance when I needed it and never too much so as to stifle original ideas. Through exposure to his philosophy of life, I have developed a deep personal respect and a lasting friendship.

I. INTRODUCTION

During an aircraft's development phase, prior to mass production, the structural strength of a component can be determined by employing destructive testing techniques. Destructive testing is used to determine the performance envelope that will serve as an operational limit throughout the structure's useful life. However, this type of testing is not feasible for in-service structures or as a monitoring process for determining performance degradation with fatigue.

From an accidental overstress or due to simple fatigue with aging, the need to compare actual performance with that predicted or specified in the contract can arise. Several non-destructive evaluation techniques include dye penetrant, eddy current and ultrasound. However, these techniques are limited in that they can only identify failure and can not determine over-stresses or gradual degradations in performance. Dynamic response testing and static load and deformation tests can locate these types of faults. If the results of a particular test are not within the specified envelope, the response testing of the full structure can assist in focusing in on the failed zone or component. Maintenance action can then concentrate on that area and a reduction of cost and down time will result. Therefore, a working knowledge of non-destructive response methods for determining strength or structural integrity of aircraft components is essential.

The need to upgrade the Naval Postgraduate School Aeronautics Department Structures Laboratory was the motivation for this study. The Aeronautics Department has a section of P2V wing which was being used for laboratory static structural tests in conjunction with several core courses. The former data acquisition system consisted of a patch panel with a manual switching network connected to a single voltmeter. Test operators were capable of observing one data point at a time. The data was recorded manually. After all data points had been taken, the tedious data reduction process commenced. Data interpretation and visualization could only be done after the data had been completely reduced which frequently occurred days after the test had been completed.

The purpose of this thesis was to modernize the data acquisition and control system, and not include the content of the static test. Therefore, the decision was made to retain the P2V wing. While the P2V has not seen active service since the 1970s, the principle of construction in it's wing structure is still being used throughout the aircraft industry. Therefore, the educational content of the structural testing is still appropriate.

This thesis was undertaken with several goals in mind. Improvements would include the opportunity to simultaneously observe multiple data points during the static testing procedure. The operator would be given the chance to interactively change the test plan at any time to investigate an area highlighted by the real-time data reduction and display. Multiple interpretations of the reduced data would be available while the static test was still in progress and decisions could be made affecting the testing plan based on those interpretations.

II. BACKGROUND

The P2V wing section was obtained in the late 1950s from the storage yard at Davis-Monthan Air Force Base. It measures three hundred and eighty-one inches from the outboard side of the starboard engine nacelle to the wing tip, wing station 192 to station 573 [Ref. 1]. One hundred and eight paper backed wire strain gages were mounted on the wing surface and interior structural members. These gages were in single elements and in three-element forty-five degree rectangular rosettes. A manual switching network with an analog voltmeter was used for the strain measurements. The wing's load application structure consisted of hydraulic actuators capable of applying pure torsional loads only. The load monitoring system was analog dynamometers. All data acquisition, reduction and analysis was done manually. In the years since the 1950s, approximately one third of the installed strain gages had deteriorated.

III. MODERNIZATION PROCEDURE

A. HARDWARE

An IBM PC/AT equipped with a National Instruments General Purpose Interface Bus (GPIB) is the center piece for this modernization approach. The GPIB installs into one of the computer's expansion slots and functions as a link or interface system, through which interconnected electronic devices communicate. In this application the electronic devices are digital voltmeters and they were connected to the GPIB in a linear configuration (daisy chained) by shielded twenty-four wire conductor cables with both a plug and receptacle connector at each end.

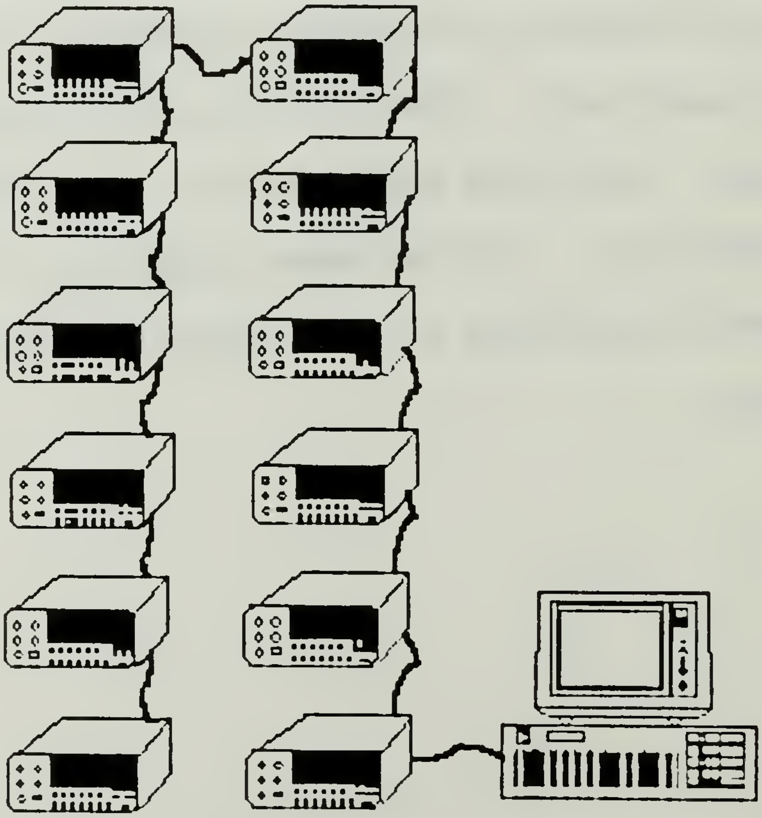

Figure 3.1 Linear GPIB Connection of Digital Voltmeters

In order to achieve the high data transfer rate that the GPIB was designed for between connected electronic devices and the bus, reference 2 lists the physical limitations for all hardware attached to the National Instruments GPIB. However, the data transfer rate of the GPIB was not limited by physical constraints in this application, but by a conflict created by the digital voltmeters command sequence which will be discussed later.

The GPIB comes equipped with an initialization routine which must be run prior to any bus utilization. This routine requires bus address assignments and the naming of all devices connected to it. It then builds a file called GPIB.COM which must be on the default directory during boot-up. When the computer is brought on line, the automatic CONFIG.SYS procedure activates the GPIB.COM file and the bus settings are initialized.

All hardware connected to any GPIB must have the IEEE-488 interface installed. This interface is essential, because it contains the dip switches necessary for device coding and it has the required cable receptacle. Those dip switch setting constitute the device's coded name and are inputted on the GPIB.COM file. It is through those dip switch settings and the initializing GPIB.COM procedure that the computer recognizes the type of device and the location of the device within the linear chain.

There are twelve Fluke 8840A multimeters connected to the GPIB. All twelve have the required IEEE-488 interface option installed. Reference 3 contains further information on the IEEE-488 interface. The Fluke meters were chosen for their accuracy, speed in measurement and primarily their ease in programming. The 8840A has a set of device-dependent commands which correspond directly to the front panel controls and can be sent to the meter via the GPIB bus when in the REMOTE mode of operation [Ref. 4]. The multimeter performs the analog to digital conversion of all measurements and the GPIB can obtain the meter reading directly.

A desirable feature of the Fluke 8840A is the OFFSET function which sets a relative datum from which all subsequent readings are taken. It was this OFFSET function that presented the data transfer problem to the GPIB. The GPIB's data transfer rate is so rapid that if any attempt is made by the computer to set the OFFSET first and then trigger a reading in the same command string, an "ERROR 32" occurs. "ERROR 32" indicates that OFFSET was selected when a reading was unavailable or overrange. The OFFSET feature must be sent exclusive of any trigger command in a single instruction string. The multimeter's output received by the GPIB is in the form of an eleven character alphanumeric string and before any arithmetic operations can be performed on it, conversion to a numerical string is required.

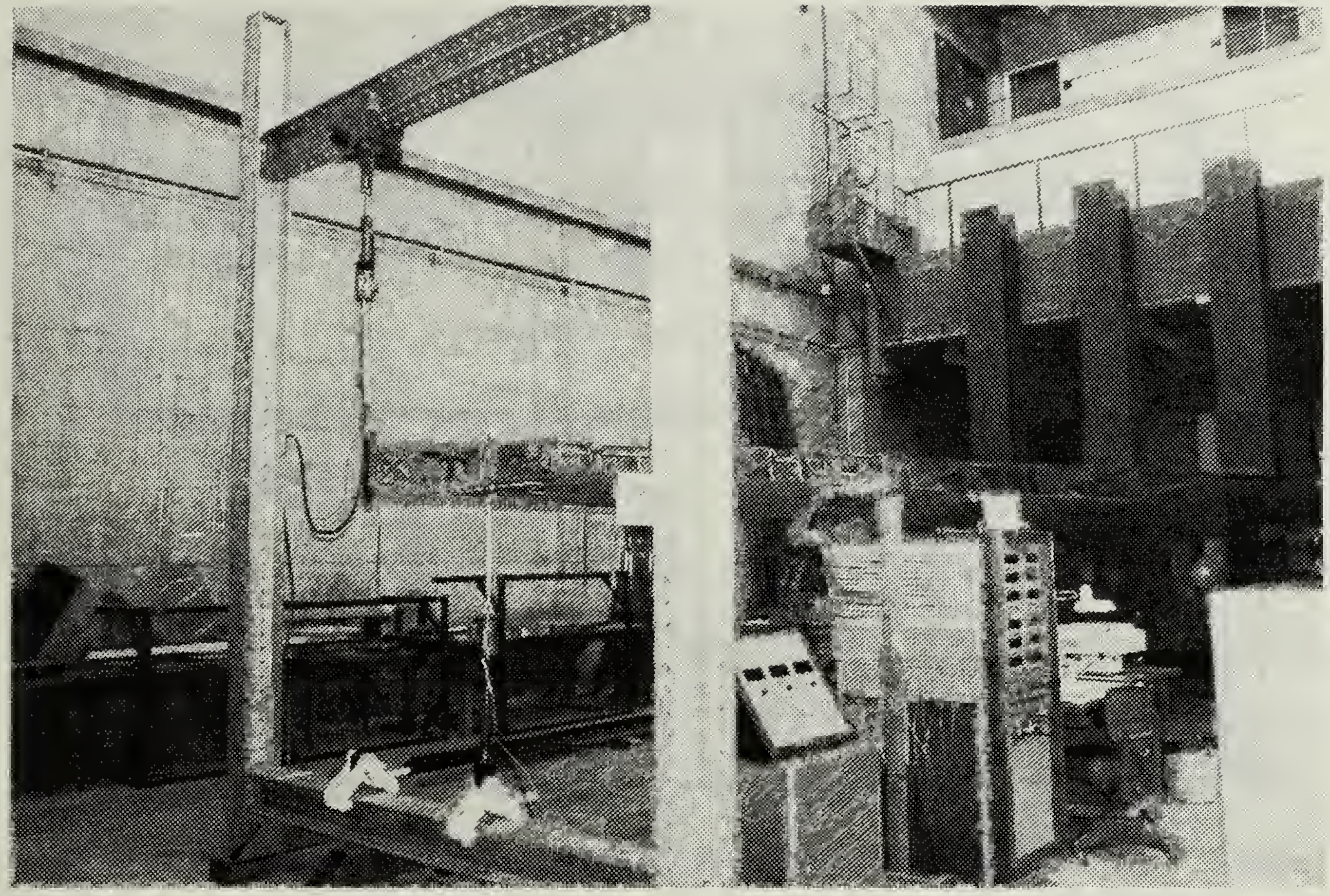

Figure 3.2   Load Application Structure

The entire load application structure was dismantled and a new frame constructed. The frame is made of fifteen and ten foot length beams of one-half inch alloy aluminum attached by bolts to the floor. The frame is designed to provide several load options: pure bending, pure torsion or a combination. Due to the simplicity of the connecting hardware, reconfiguring for different load applications will take minimal time. All connecting hardware was designed or specified to withstand a maximum of four thousand pounds of force in tension. The wing structure's load limitation is two thousand pounds with the front spar web installed. A stability analysis was done on the frame and those results are contained in Appendix C.

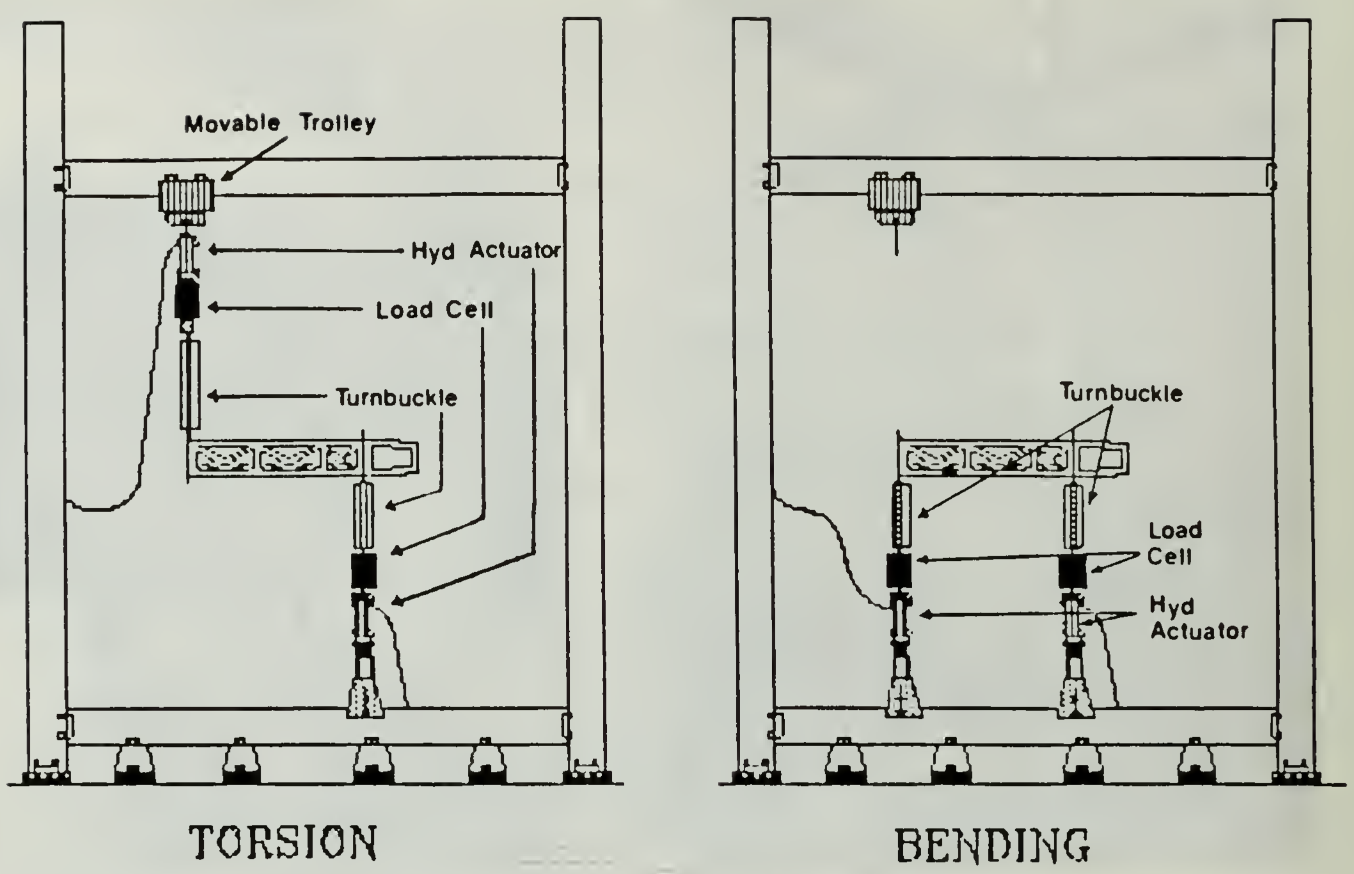

Figure 3.3 Load Application Structure Configurations

A Baldwin-Lima-Hamilton load cell was installed in series with each of the two hydraulic actuators. These load cells provide the load monitoring transducer when connected to separate digital voltmeters at the load cell panel. The meters were calibrated to read directly in pounds of force tension. Appendix B contains the calibration statistics and procedure. These meters can not be read directly by the computer and therefore must be manually monitored during loading and their results entered into the program when prompted. Load cells one and two are currently connected to the structure. The number three load cell is a spare or it can be used as a third load monitor in different multiload configurations.

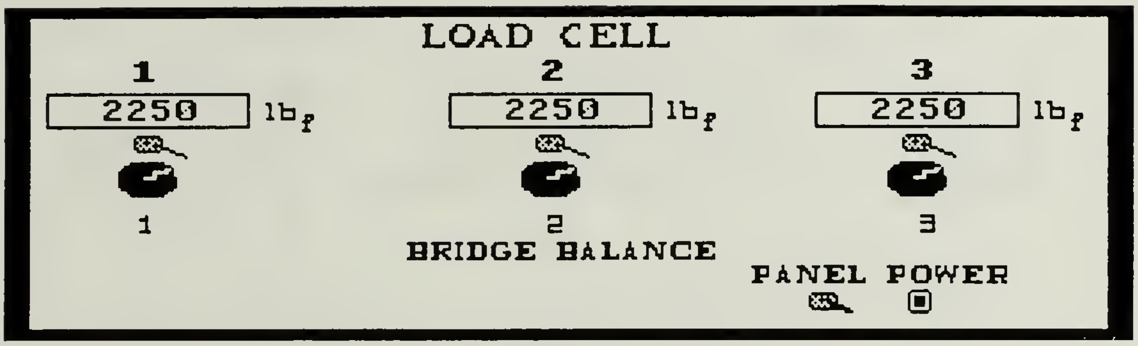

Figure 3.4 Load Cell Monitoring Panel

Approximately thirty of the mounted paper-backed wire strain gages had failed since the 1950s. These were removed and operable paper-backed wire gages were installed in their locations. Additionally, newer generation epoxy-backed foil gages were installed in strategic locations internal to the wing structure on the hat and stringer sections. Appendix A contains the strain gage location information. These new gages were located adjacent to the older style gages in order to provide comparisons between gage types and the different lay-ups of the rosettes.

The new strain gage rosettes were purchased specifically to optimize measurements in shear and they will provide the highest resolution in determining the two Mohr's circle invariants; radius and circle center location along the X-axis. Perry/Lissner and Beer/Johnston provide further information on the Mohr's circle interpretation of strain gage rosette data [Refs. 5, 6].

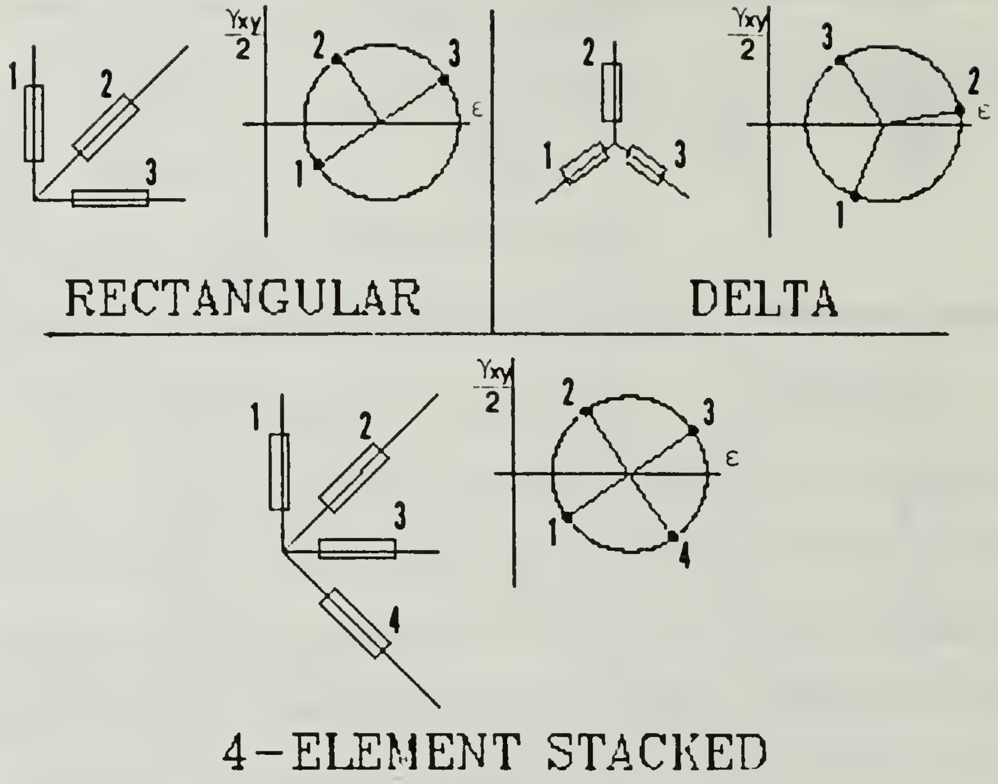

Figure 3.5 Strain Gage Lay-up Mohr's Circle Resolutions

B. SOFTWARE

The National Instruments GPIB comes equipped with a handler written in IBM BASICA. BASIC was chosen as the controlling software for it's general acceptability, ease in programming and powerful color graphics capability. The IBM PC/AT is equipped with an Enhanced Graphics Adapter (EGA) and Enhanced Color Monitor. BASIC is one of only a few programmable languages which currently utilizes the screen resolution and color offered by this combination; 640 screen pixels in horizontal, 350 screen pixels in vertical, sixteen colors.

The BASIC program consists of three separate programs which are linked together by the CHAIN statement; P2V-CAL.BAS, P2V-LOAD.BAS and P2V-ANAL.EXE. All three program listings are contained in Appendix D. These programs perform five major procedures:

(1) Updating the installed strain gage's resistance in the hard disk's memory.

(2) Calculating a strain gage's calibration factor based on a shunt resistance measurement.

(3) Loading the wing and measuring the strain gage output with graphical analysis of the results.

(4) Graphically analyzing the last set of data displayed.

(5) Adding, deleting or replacing strain gage hardware installed on the wing.

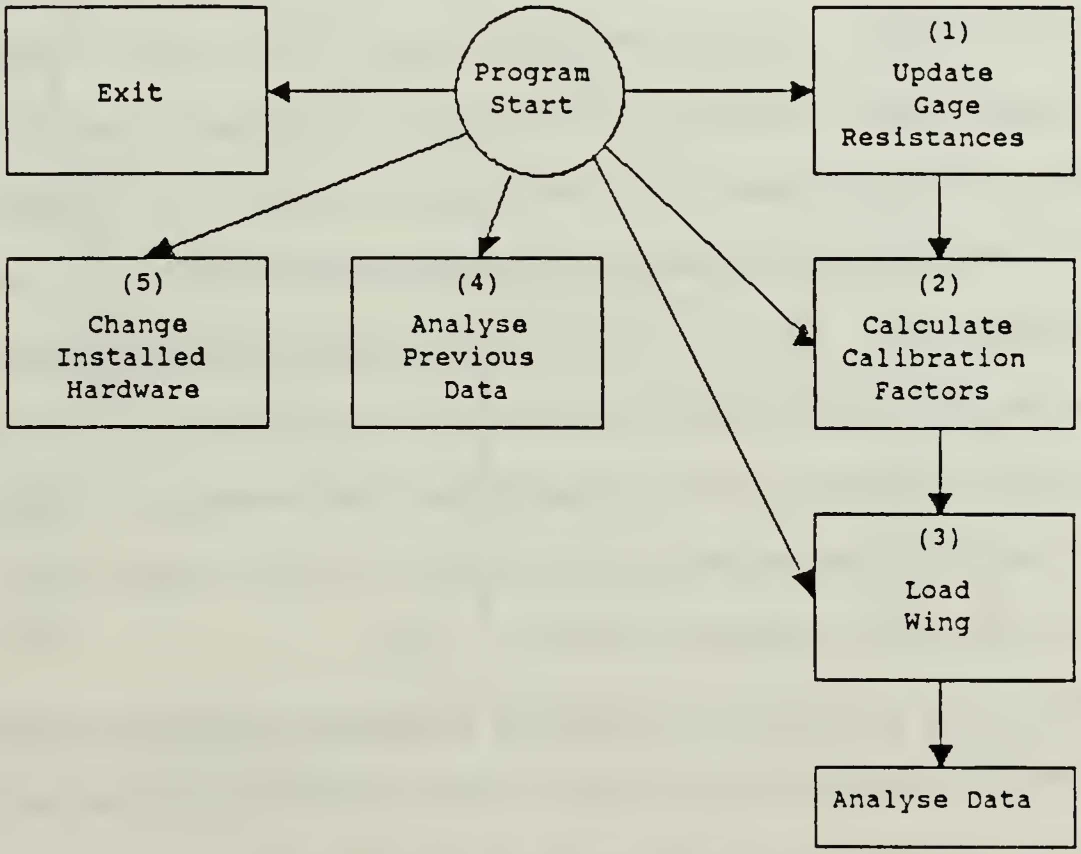

Figure 3.6 Controlling Software Program Structure

Procedures (1) through (3) should be done sequentially. However, since the result of each procedure is stored on the internal hard disk, all three need not be completed in a single session. Procedure (4) exists primarily to demonstrate the graphics portion of the program. Procedure (5) is to be used only when changing the strain gage configuration.

The graphical display of the strain gage data comes in two forms; the traditional Mohr's circle and a pictorial representation of a area's surface element deformation. (See Fig. 3.7) The surface element deformation display presents a square depicting an element of wing surface before load application and the deformed square by the applied load as calculated from the strain gage rosette at the respective location. In order to better observe changes in the loaded element, an isotropic strain multiplier is used if the strain level is below five tenths of a micro-inch per inch. Park's Interactive Microcomputer Graphics contains the information necessary to write algorithms that accurately display the elongations and rotations associated with the strains experienced by the wing's structural members on the computer monitor [Ref. 7].

The most difficult obstacle encountered in programming was interfacing the IBM PC/AT with the Hewlitt Packard Laserjet printer. The Laserjet does not have an installed

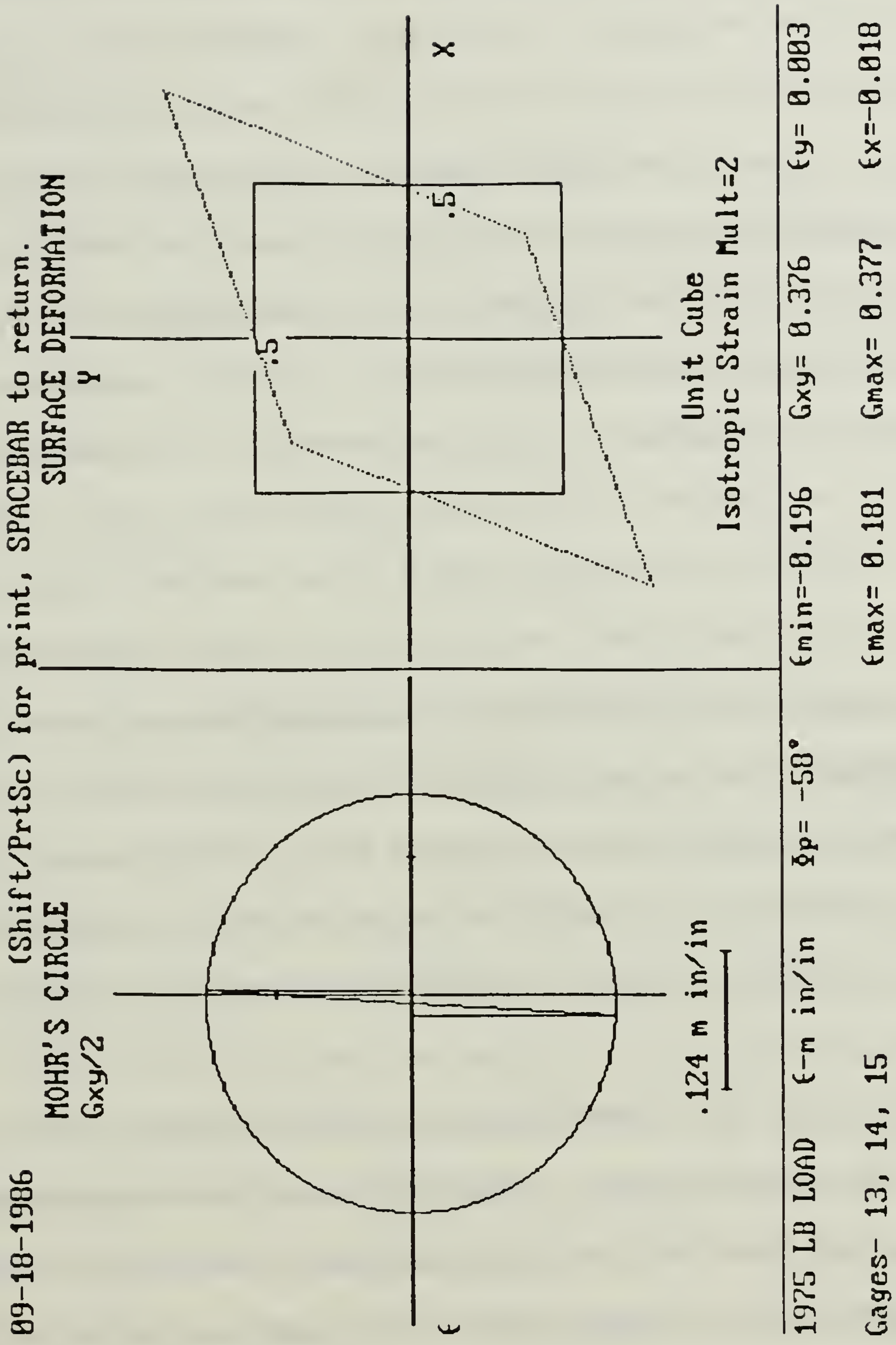

Figure 3.7 Sample Print of Graphical Analysis of Strain Gage Data

screen graphics print capability. As a result, an after-market screen utility GRAFLASR [Ref. 8] was purchased to perform this necessary function. However, the screen print utility was not compatible with IBM BASICA in the highest possible screen resolution mode. Therefore, in order to get high resolution graphics printing directly from the screen display, the program P2V-ANAL.EXE was written in the form of a compiled BASIC executable file. It was compiled using Microsoft's QuickBASIC compiler version 2.0 [Ref. 9]. When graphical analysis is selected immediately after the print of the tabularized loading data, the program stores the current applicable data on the hard disk. Then IBM BASICA is terminated and the compiled executable program takes over and executes the screen graphics commands after it inputs the necessary data from the hard disk. The screen print is not attempted in the BASICA environment but under DOS, the normal operating system's environment and no conflict exists.

Initially, the Laserjet distorted the vertical axis during the screen print. GRAFLASR's printer driver software file for the Hewlitt-Packard Laserjet had to be modified with respect to the vertical axis print scale in order to get the exact dimensional proportions displayed on the screen printed on the paper.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

An IBM PC/AT equipped with a GPIB connected to strain measuring devices can provide a real-time data acquisition and display system for complex static structural tests. Software can be written to provide various graphical representations of the results giving several options to the operator.

B. RECOMMENDATIONS

The most time consuming task in the static testing procedure involves the optical deflection measurement system currently installed. Ten rulers are suspended from the wings underside at known wing stations. They are sighted with a surveyor before and after loading to determine deflections. This system is replete with opportunities for human error. One solution would be the installation of a low power laser with several sensor stations along the wing to measure the beam's deflections. Also, the connection of simple deflection gages to various stations along the wing via cable system would give highly accurate readings with the possibility of human error greatly reduced.

Due to simplicity of the load application frame's construction and the availability of additional parts, it would be easily expanded to adapt to larger and more complex loading configurations. Multiple bending and torsional loads along the wing and an aerodynamic load could be possible.

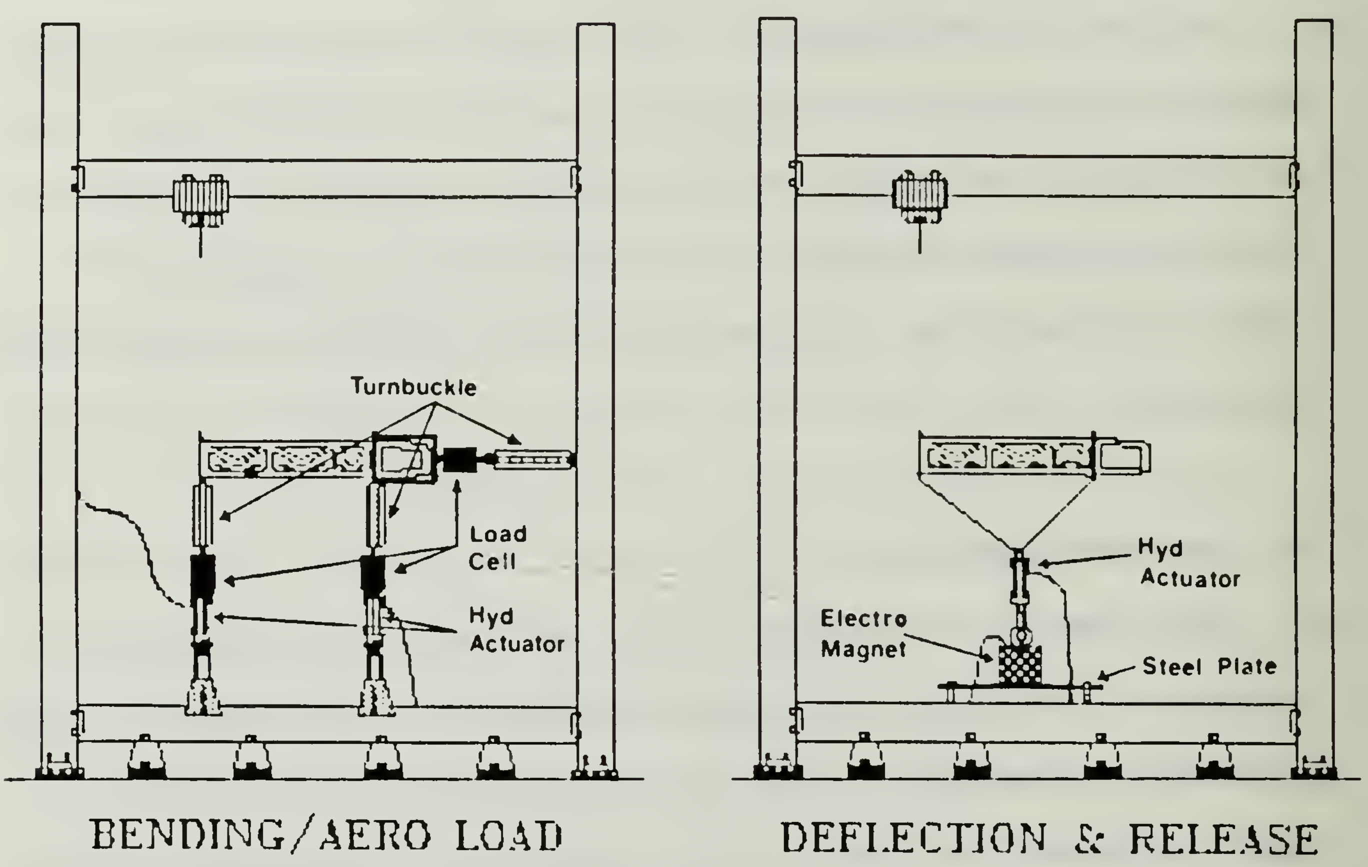

Figure 4.1 Possible Loading Configurations

The IBM PC/AT is expandable to many different applications. The Aeronautics Department has a commercial software program called ENTEK [Ref. 10] which is capable of interpreting dynamic response data. Purchase of a precision hydraulic vibration rig capable of selectable frequencies and amplitudes or the simple deflection/release apparatus shown in Figure 4.1 could expand the current topics of evaluation to include some areas of dynamic response testing.

LIST OF REFERENCES

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4. John Fluke Manufacturing Co., Fluke 8840A Multimeter Instruction Manual, pp. 3-5 to 3-7, 1984.

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6. Beer, F.P. and Johnston, E.R., Mechanics of Materials, pp. 340 - 347, McGraw-Hill Book Co., 1981.

7. Park, C.S., Interactive Microcomputer Graphics, pp. 109 - 113, Addison-Wesley Publishing Co., 1985.

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APPENDIX A

P2V WING OPERATOR'S GUIDE

A. PRELIMINARY

Prior to commencing this experiment, two decisions must be made. First, the type of load that will be applied to the wing; pure torsion or pure bending. Second, which strain gages will be monitored on the wing during the application of that load. The gages should be chosen based on the type of analysis desired and the load applied.

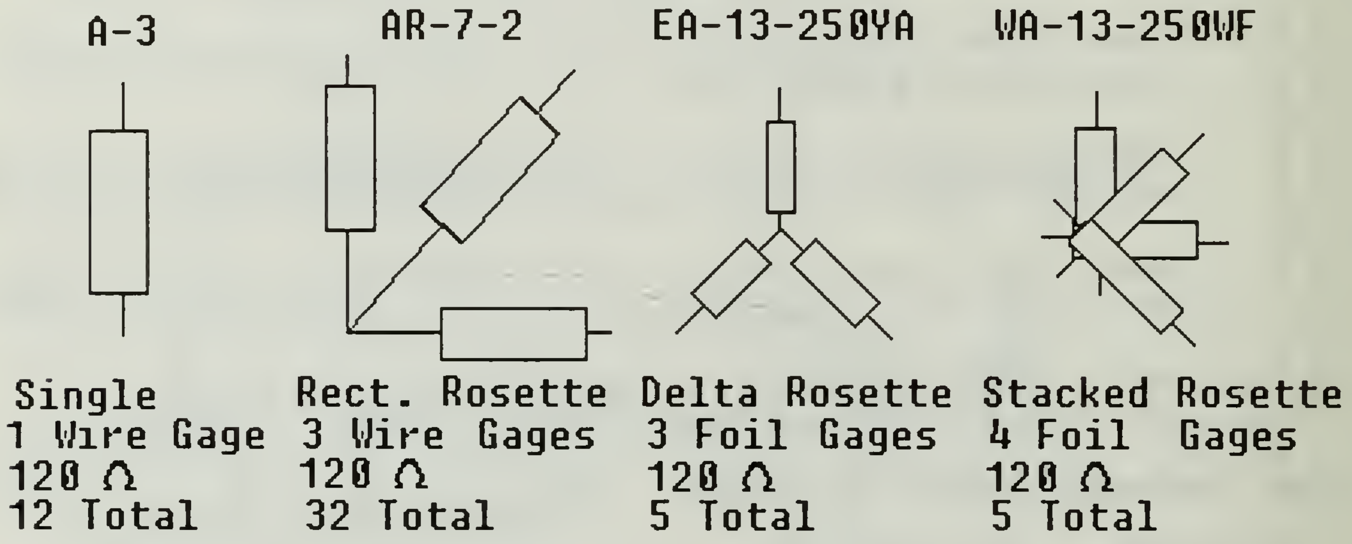


Figure 1.A Strain Gage Descriptions

There are 143 individual strain gages installed on and inside the wing. Most are in strain gage rosettes but there are 12 that are single element gages. 108 are older wire gages and the rest are newer generation foil gages. Table I.A is a listing of strain gages by type. Figures 8.A, 9.A, 10.A and 11.A "P2V STARBOARD WING, Strain Gage Locations" contain a complete description of gage positions.

CAUTION

> Twelve gages, all of the same type, should be monitored during each program run. Since there is only one unloaded temperature compensating gage used to complete the Wheatstone bridge circuit for the twelve loaded gages, any attempt to mix strain gage types will result in erroneous data.

B. SETUP

(1) Remove and stow the equipment covers.

(2) Connect the desired gages to the DVM leads at the strain gage peg board. Also, connect the compensator leads to the type of strain gage being monitored. The unloaded temperature compensator gage female connectors are in the lower right corner of the upper peg board. They are enclosed in a yellow boarder and are numbered 147-150.

CAUTION

When monitoring rosettes, keep the rosette gages in sequential order with respect to the DVMs.
Example 1: rosette with gages 68, 69, 70 connected to DVMs 1, 2, 3 and then rosette with gages 21, 22, 23 connected to DVMs 4, 5, 6.
Example 2: rosette with gages 136, 137, 138, 139 connected to DVMs 1, 2, 3, 4 and then rosette with gages 140, 141, 142, 143 connected to DVMs 5, 6, 7, 8.

(3) Apply power to the following equipment:

- Computer and Monitor. As the computer comes up, it will commence a power-on self test. The self test and the subsequent loading of the initial batch file is automatic and requires no action by the operator. The monitor has brightness and contrast controls directly beneath the on/off knob. Do not set the brightness to the extreme as prolonged use at this level may cause permanent damage to the screen.

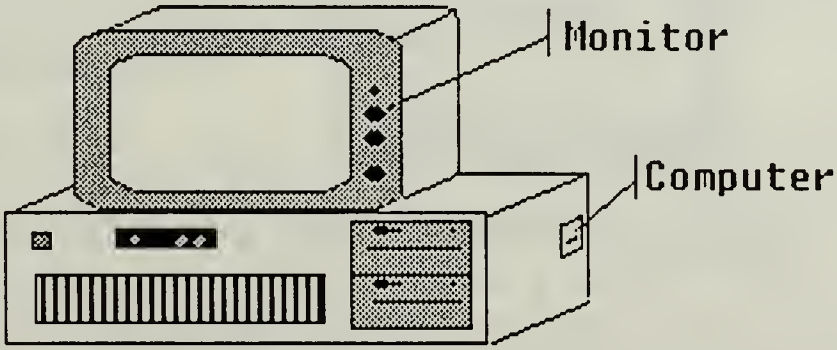


Figure 2.A Computer and Monitor Power Supply Switch Locations

- Printer. The printer has a power-on self test. The computer must be turned on prior to the printer or a logic error will occur in the printer's self test. The printer indicates it's ready to print when the number 00 is in the status window.

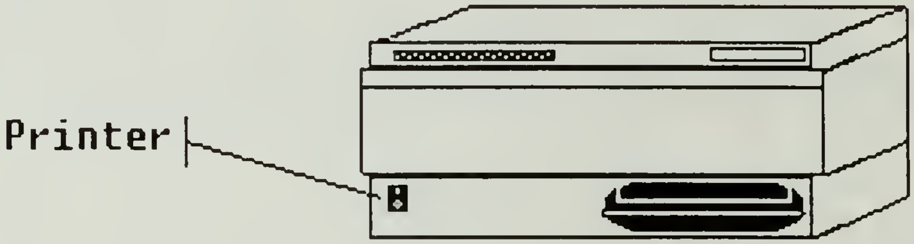


Figure 3.A Printer Power Supply Switch Location

- DVM Column Master, Individual DVMs and the Voltage Power Source. The DVM column master switch is a push button type on/off switch. Wait until the DVM column cooling fans are fully up to speed prior to energizing the individual DVMs and the voltage source. Only the right side of the voltage source is currently being utilized. Do not adjust the DVMs or the voltage source at this time.

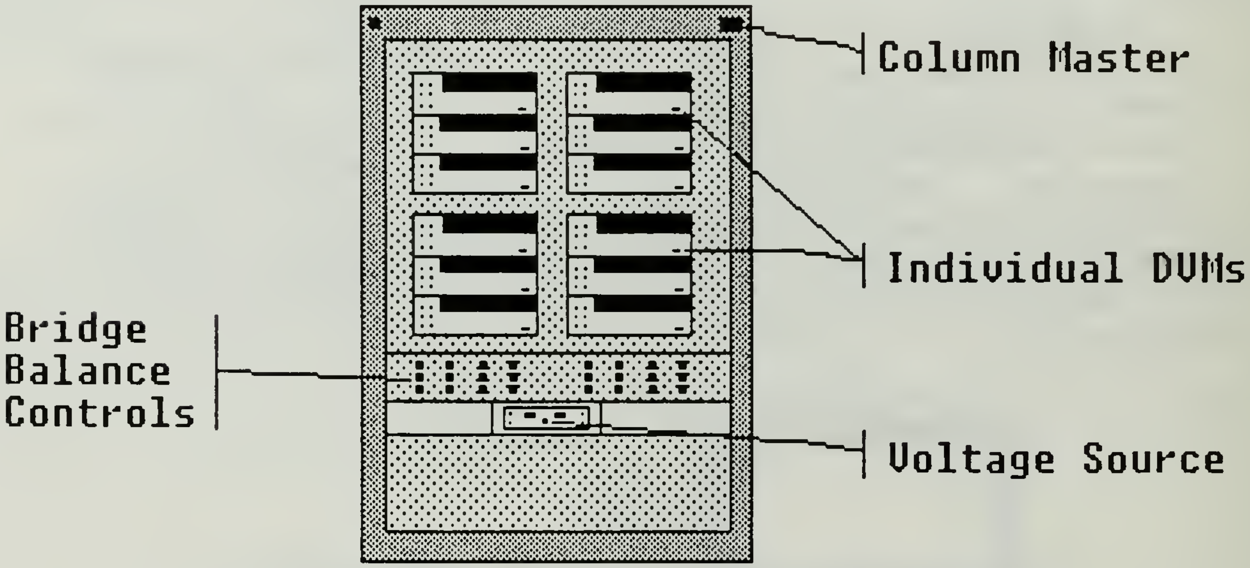


Figure 4.A Digital Voltmeter Column Power Supply Switch Locations

- Load Cell Panel Master and the Individual DVMs. Do not attempt to zero the DVMs.

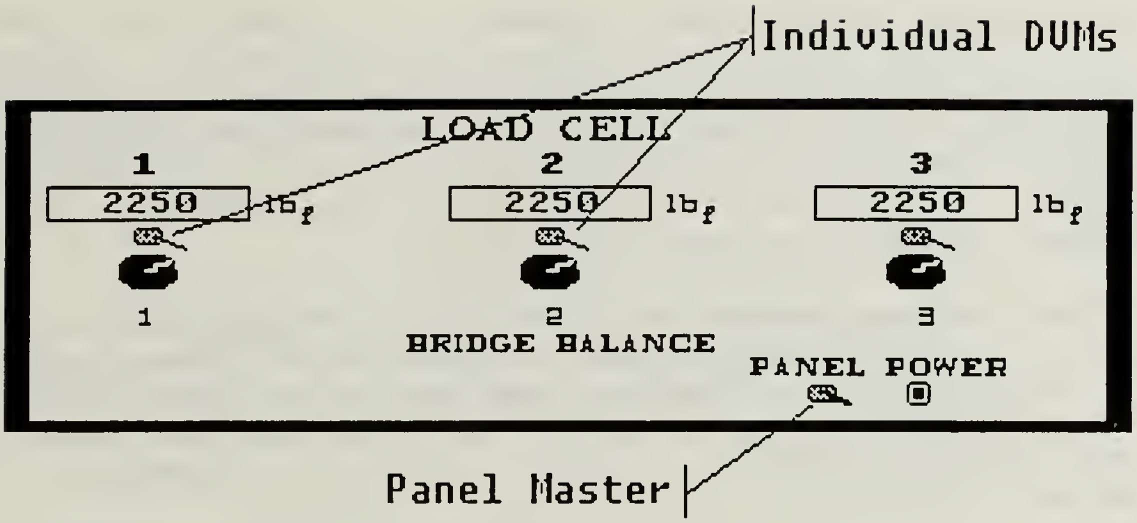


Figure 5.A   Load Cell Panel Power Supply Locations

C. PROGRAM EXECUTION

The program (P2V) is stored on the internal hard disk so no disk loading is necessary. P2V and all the utilities necessary to run it are in the \GPIB-PC sub-directory. A batch file is available to make access simple.

(1) At the system prompt, C>, type "P2V" and then hit Enter.

First, the utilities load, then the program will run. The program is structured into five main procedures:

1. Updating strain gage resistances.
2. Obtaining calibration factors based on a shunt resistance measurement.
3. Loading and measuring strains with a graphical analysis of rosettes.
4. Analyze the last set of load data which had previously been displayed. This procedure is primarily for demonstration purposes.
5. Adding/deleting/replacing strain gages on the installation.

Procedure 5. is to be used only when changing hardware installed on the wing. The other three procedures should be done sequentially. Since the results of each procedure are stored on the hard disk, it is not necessary to do all three procedures in one sitting. For example, strain gage resistances are updated and then the calibration factors computed. If the system is secured and then restarted the next day, the experiment can commence at procedure 3 since all the previous data has been stored on the hard disk.

Hints on running the program:

- Due to a bug in IBM BASICA the backspace key has been disabled. To correct previously typed errors prior to hitting Enter, use the direction keys on the numeric keypad. If you inadvertently hit the backspace key, a window appears telling you what to do.

- When making strain gage resistance measurements, the leads for DVM 1 should be the only leads connected to the strain gage. If other DVM leads are left connected and a resistance measurement taken across the gage, the reading will include the DVM resistance in parallel with the strain gage.

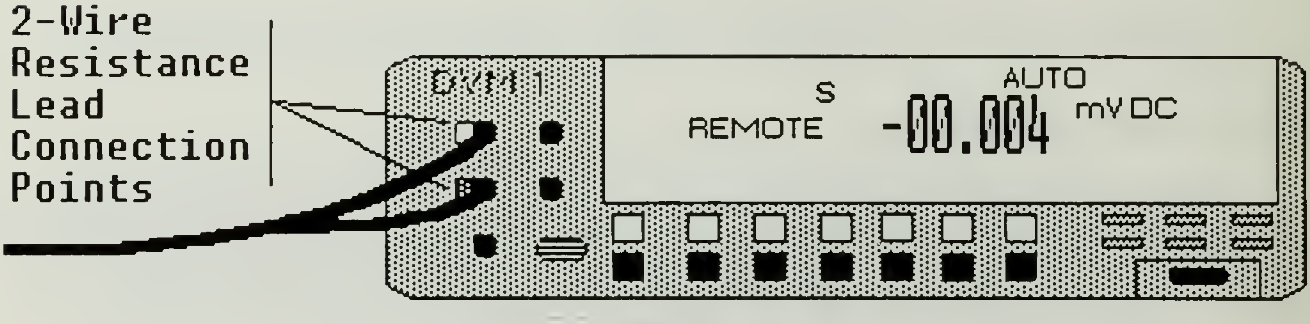


Figure 6.A DVM1 Resistance Lead Connection Points

- Several times in the program a screen dump to the printer occurs. The print takes approximately two minutes for a text screen and three minutes for a graphics screen. A flashing statement will appear when a print is in progress, except for a graphics screen. Program execution halts during a screen dump.

- Do not waste allot of time trying to balance the Wheatstone bridge circuits to zero. Get them as close as possible to keep current flow to a minimum. Since the Fluke meters utilize an OFFSET function, exact zero is not necessary.

- Analysis of the strain gages rosettes being monitored can be accomplished by the program with graphical results only immediately after the screen print of the load summary. If the choice is made to get additional load data without doing the analysis, the opportunity for the program to calculate the analysis is lost for that set of load data.

- Only as a last resort, the program can be terminated at any time by hitting Ctrl/Break simultaneously. To clear the screen and return to the primary text screen, hit F10. To rerun the program from this point, type SYSTEM, Enter and then P2V. The initial selection menu should now be in view.

CAUTION

Exit from the program using the Ctrl/Break procedure can cause loss of computed data up to that point. For normal program termination, use one of the Exit options in a program selection menu.

D. HYDRAULIC OPERATIONS/WING LOADING

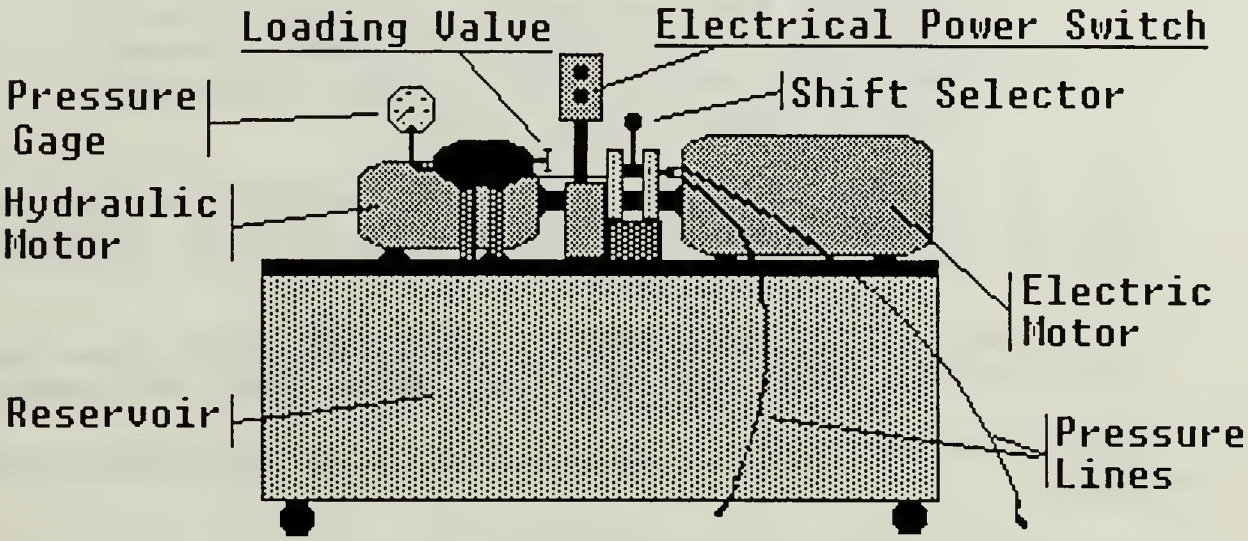


Figure 7.A Hydraulic Loading System Component Location

The hydraulic loading system consists of an electric motor which drives a constant pressure hydraulic pump to provide pressure via two lines to actuating cylinders attached to the wing. Prior to actuating the electric motor ensure that the loading valve is open (spins freely counter clockwise) and the shift selector is in the NEUTRAL position.

(1) START the electric motor. Allow at least 3 minutes of warm up prior to loading.

(2) Zero the load reading at the Load Cell Panel by using the bridge balances.

(3) Place the shift selector in the P2V WING position and pin it. A slight load might appear on the load meters due to leakage at the loading valve.

(4) Slowly turn the loading valve clockwise. Several turns may be required prior to the first indications of hydraulic loading, depending on how far out the previous operator set the valve. Scan the load meters and the hydraulic pressure gage for indications of system loading.

CAUTION

> Hydraulic system hysteresis evidenced by a large split in load meter readings is best avoided by a slow, smooth and continuous turn of the loading valve to the desired load. A large split will occur if the desired load reading is overshot and the system unloaded down to the value. If a gross overshoot occurs, completely unload the system, reset the DVMs to zero and try again.

(5) If a split between load cells exceeds say 2% of the desired value, completely unload the system, reset the DVMs to zero and try again.

(6) Load limits are 2100 lb. with the front spar web installed and 1050 lb. with the front spar web removed.

Hints on successful operation of the hydraulic system include:

- When turning the loading valve make slow, smooth and continuous turns. Do not loose patience and rapidly turn the valve.

- Set zeros at the Load Cell Panel only when the loading valve spins freely counter-clockwise and the shift selector is in neutral.

- If the system has not been used for an extended period, load the system up to 1000 lb. to exercise the linkage, then unload and set the zeros prior to attempting a program run.

- A plumb bob is suspended from the upper support member. A sliding scale is mounted beneath it. Prior to loading, set a convenient reading as zero and occasionally monitor structure deflection if at the load limit. The deflection should never exceed one-half inch.

E. SECURE

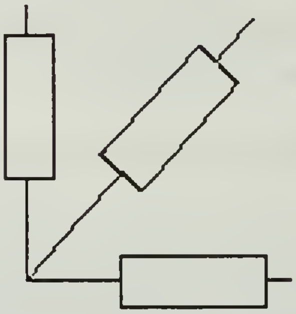
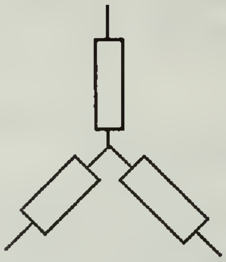
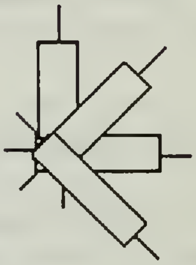
When securing the equipment associated with the wing, order is important for the following:

- DVM Column. First secure the individual DVMs and the voltage source, then the column master.

- Load Cell Panel. First secure the individual DVMs and then the panel master.

- Hydraulics. Always unload the wing at the loading valve and put the shift selector in neutral prior to securing the hydraulic pump electrical motor.

TABLE I.A LIST OF STRAIN GAGES BY TYPE

A-3	AR-7-2	EA-13-250YA	WA-13-250WF
			
Single 1 Wire Gage 120 Ω 12 Total	Rect. Rosette 3 Wire Gages 120 Ω 32 Total	Delta Rosette 3 Foil Gages 120 Ω 5 Total	Stacked Rosette 4 Foil Gages 120 Ω 5 Total
19	1-2-3	109-110-111	124-125-126-127
20	4-5-6	112-113-114	128-129-130-131
36	7-8-9	115-116-117	132-133-134-135
37	10-11-12	118-119-120	136-137-138-139
71	13-14-15	121-122-123	140-141-142-143
72	16-17-18		
103	21-22-23		
104	24-25-26		
105	27-28-29		
106	30-31-32		
107	33-34-35		
108	38-39-40		
	41-42-43		
	44-45-46		
	47-48-49		
	50-51-52		
	53-54-55		
	56-57-58		
	59-60-61		
	62-63-64		
	65-66-67		
	68-69-70		
	73-74-75		
	76-77-78		
	79-80-81		
	82-83-84		
	85-86-87		
	88-89-90		
	91-92-93		
	94-95-96		
	97-98-99		
	100-101-102		

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

TOP OF TEST SECTION
BOTTOM SURFACE OF WING

NOTE: Wing is mounted upside down.

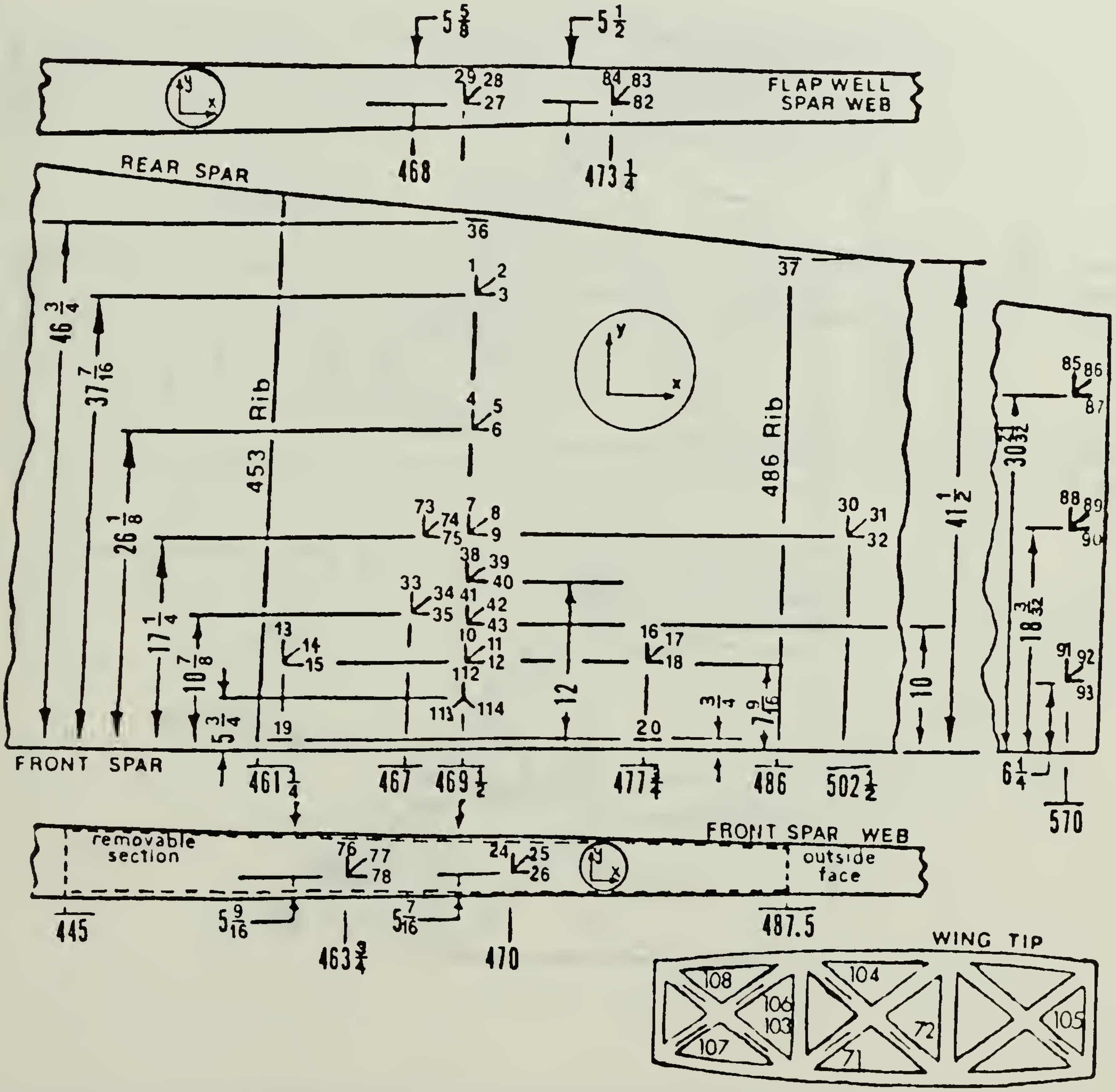


Figure 8.A P2V Starboard Wing, Strain Gage Locations, Top of Test Section

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

TOP OF TEST SECTION
BOTTOM SURFACE OF WING
INTERIOR

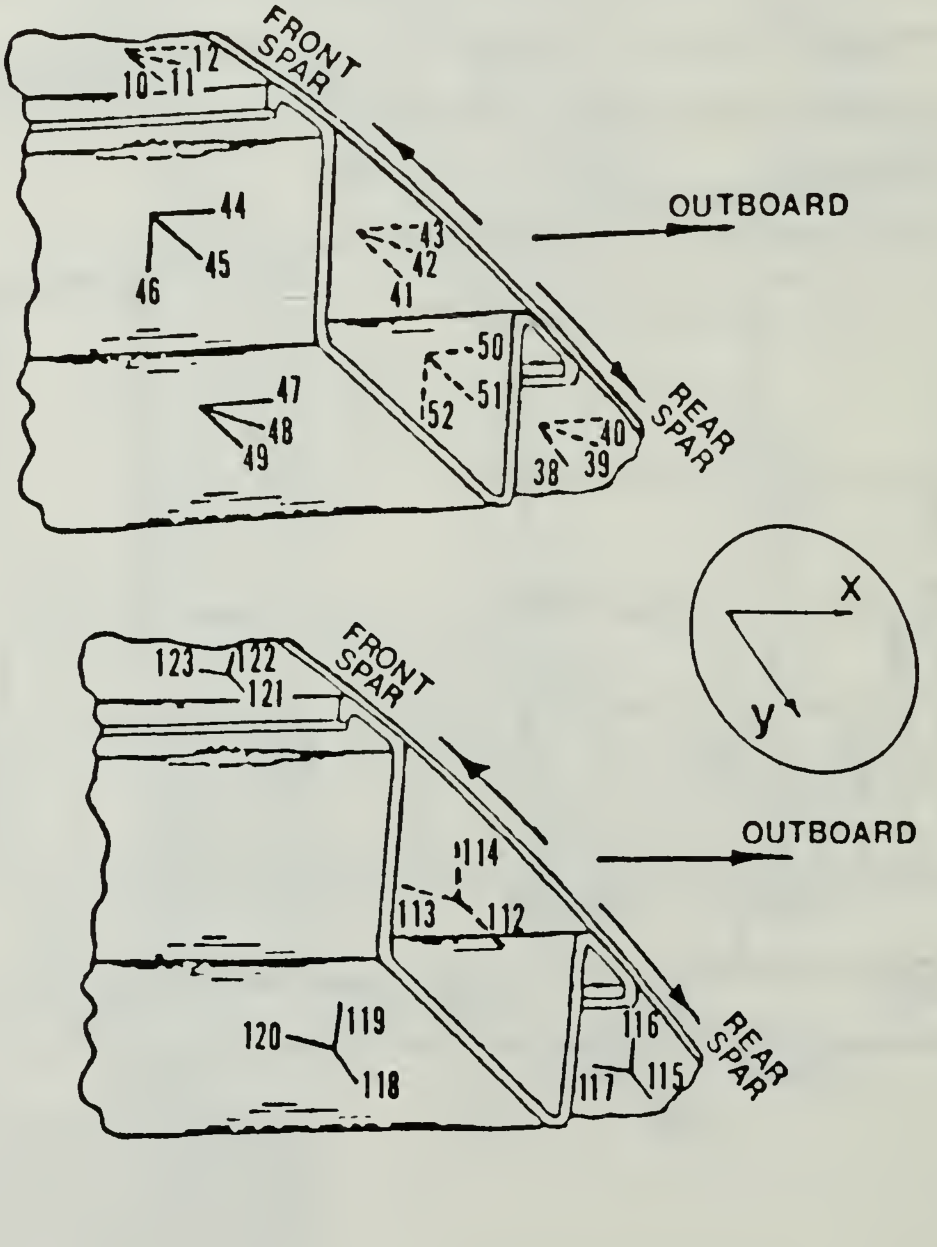


Figure 9.A P2V Starboard Wing, Strain Gage Locations, Top of Test Section, Interior

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

BOTTOM OF TEST SECTION
TOP SURFACE OF WING

NOTE: Wing is mounted upside down.

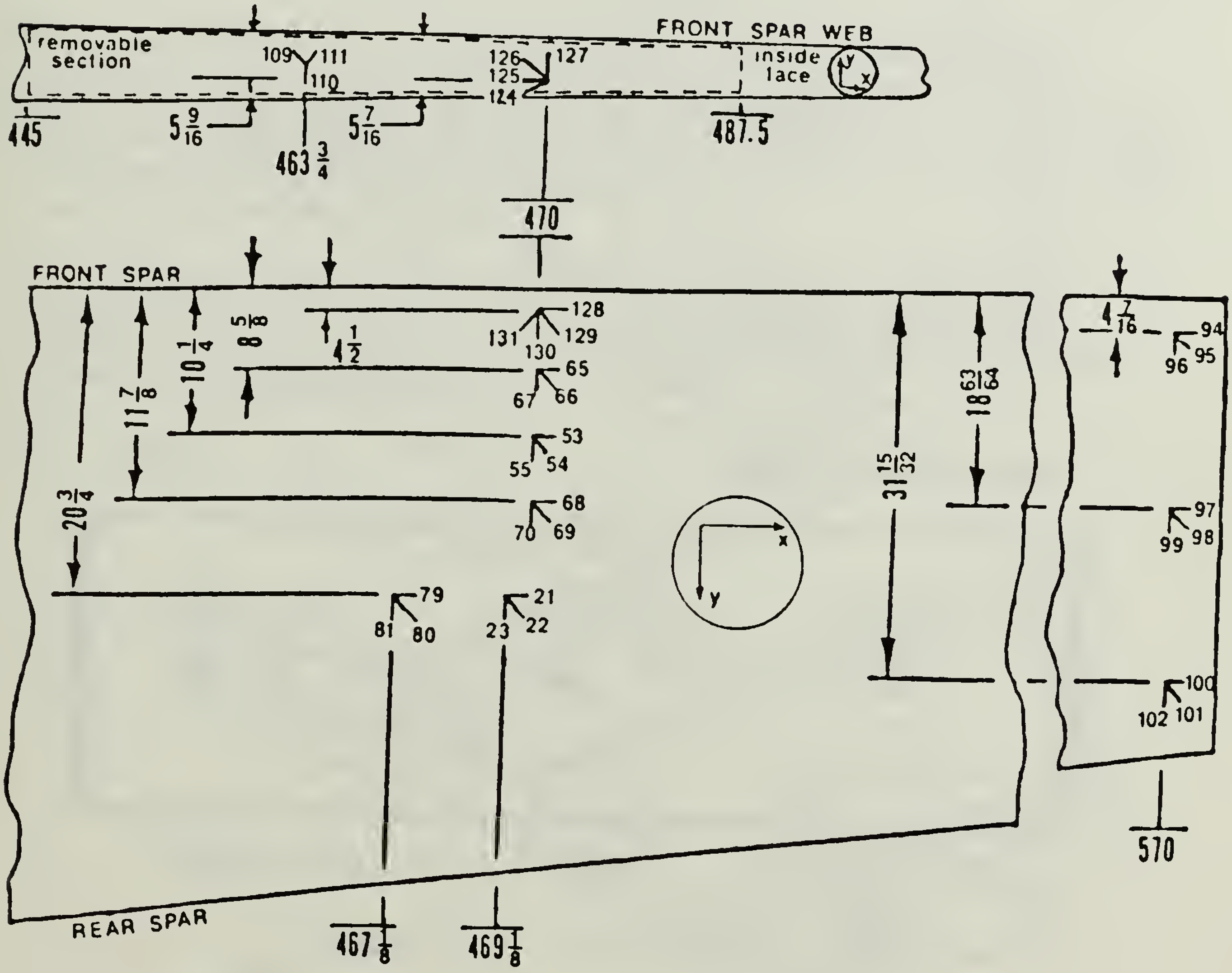


Figure 10.A P2V Starboard Wing, Strain Gage Loacations, Bottom of Test Section

P2V STARBOARD WING

STRAIN GAGE LOCATIONS

BOTTOM OF TEST SECTION
TOP SURFACE OF WING
INTERIOR

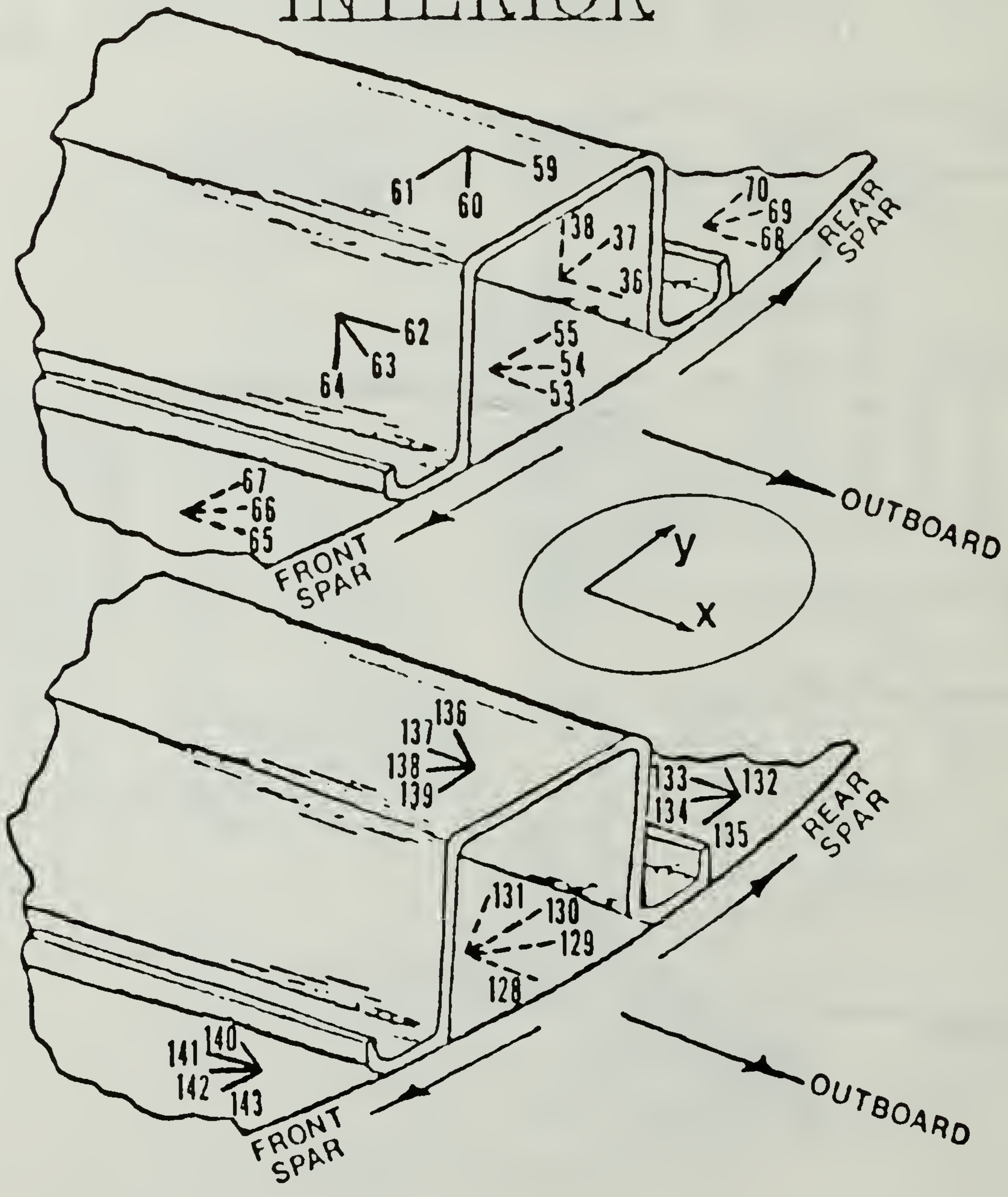


Figure 11.A P2V Starboard Wing Strain Gage Locations, Bottom of Test Section, Interior.

APPENDIX B

P2V WING LOAD CELL CALIBRATION GUIDE

A. PREFERRED METHOD

1. Remove the load cells from the support structure.

2. Install threaded shafts with nuts in both ends of the load cell. Extra threads and the nuts are in the drawer below the load cell panel.

3. Position the load cells in a test machine with proper capacity (Riehle 300,000 lb. testing machine). A solid clamp on the nuts prior to loading the machine is extremely critical for accurate readings. However, some slippage will occur during initial loading and it should be anticipated.

4. Connect the load cell cannon plugs to the load cell panel as would be in normal operations. Remove the front panel screws and tilt the panel forward exposing the interior electronics.

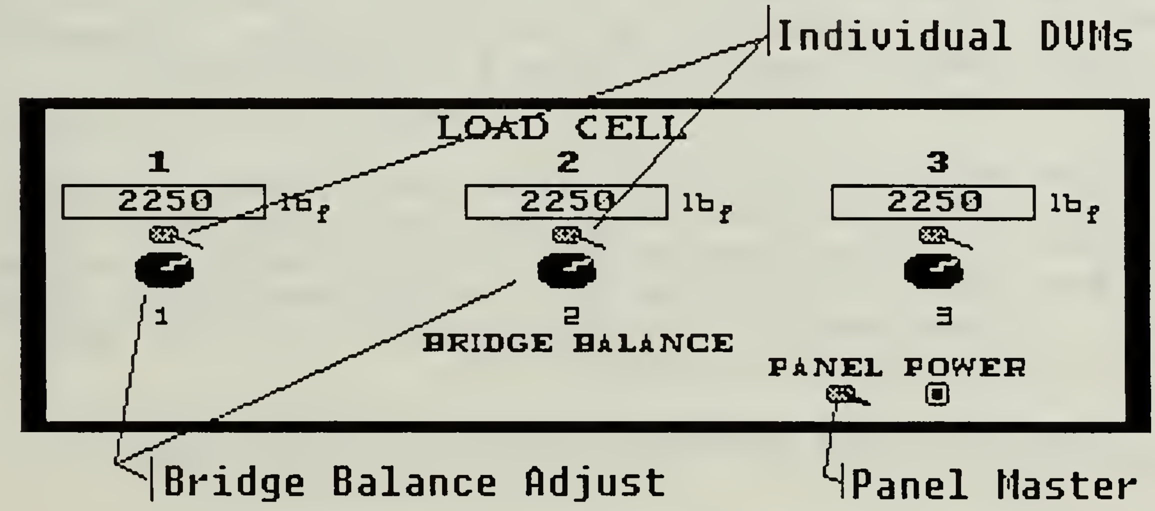


Figure 1.B Load Cell Panel

5. Each load cell has a voltage regulator and amplifier connected to a single plug in board. Locate the amplifier adjust screw that corresponds to the desired load cell being calibrated. They are from top-to-bottom 1,2,3. The adjust screw is mounted sideways on the amplifier.

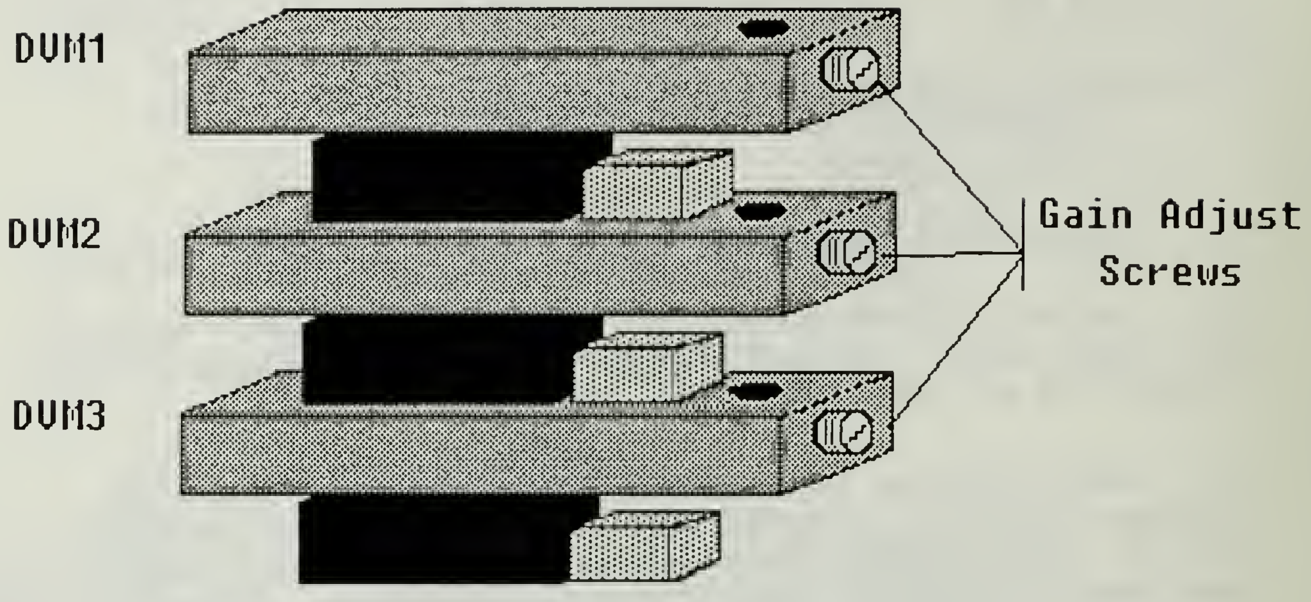


Figure 2.B Load Cell Amplifier Adjust Locations

6. Commence loading of the cell. Do not attempt to calibrate the load cell during initial loading where some clamp slippage will occur. The DVM reading will lag approximately 30 - 50 lb. during transient loading. Stop as close as possible to 2000 lb. The load machine can not hold a constant setting of 2000 lb. Therefore, it will take at least two people to successfully continue the calibration of the cells from this point.

7. One person should give short load bursts on the machine, then call out when the load passes the target of 2000 lb. The other person should attempt to adjust the amplifier so that the 2000 lb DVM reading is on the mark. A successful calibration should be considered when the readings are within 5 lb.

8. Calibrate the remaining cells using the same procedure.

9. Reinstall the load cells on the wing load application structure.

10. Immediately after successfully calibrating all three load cells, place the calibration shunt resistor across the jacks in the back of the load cell panel and record the readings. These readings will be a quick check for load cell calibration when necessary.

B. SECONDARY (QUICK CHECK) METHOD

1. Apply power to the load cell panel and the individual DVMs. After a sufficient warm-up, set zeros using the bridge balances.

2. Place the calibration shunt resistor across the jacks in the back of the load cell panel. Compare the reading against the last calibration run in the load machine. If the reading is off by more than 10 lbf., adjust the amplifier power supply as in the method described in the preferred calibration procedure.

3. Last calibration:

LOAD CELL 1	LOAD CELL 2	LOAD CELL 3	DATE
-1267	-1226	-1256	20/08/86
______	______	______	__________
______	______	______	__________
______	______	______	__________
______	______	______	__________
______	______	______	__________
______	______	______	__________

APPENDIX C

LOADING FRAME STABILITY ANALYSIS

A. TEST

The stability test on the loading frame was done with the use of a manila rope, dynnamometer and a come-along. One end of the rope was attached to the frame's cross beam, the other to the opposite wall so as to place the load axis perpendicular to the vertical support, Figure 3.C. Deflections were measured with a plumb bob attached to the cross member.

TABLE I.C STABILITY ANALYSIS DATA

Load (lb)	Moment (in-lb)	Deflection (in)	Angle (rad)
0	0	0.0	0.0
50	2600	0.07	0.0013462
100	5200	0.17	0.0032692
145	7540	0.27	0.0051923
185	9620	0.37	0.0071153
242	12584	0.42	0.0080768
312	16224	0.63	0.0121148
345	17940	0.67	0.0128839
395	20540	0.82	0.0157679
435	22620	0.97	0.0186539
485	25220	1.14	0.0232919
500	26000	1.25	0.0240338
525	27300	1.33	0.0255714
555	28860	1.42	0.0273009

B. Simplified Model

In determining the critical load for the loading frame, the following simplifying assumptions were made:

- The complete frame was reduced to a single column.

- The single column was a rigid body.

- Loading on the column was precisely vertical.

- The vertical load was concentric on the column.

- All resistance to torsional load deformation was reduced to a torsional spring located at the base of the column.

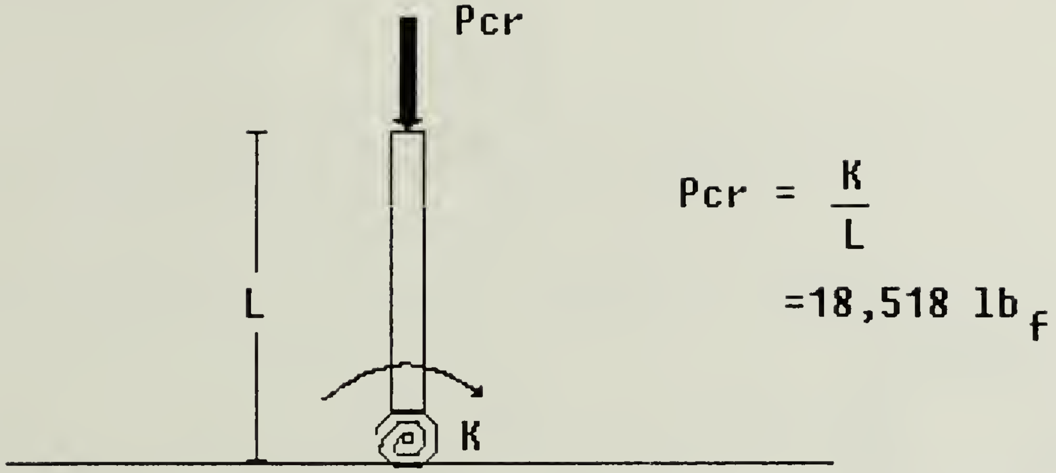


Figure 1.C Simplified Load Frame Model

Figure 2.C contains the plotted data from the deflection test. After a linear regression of that data, a best-fit value for the slope K, the torsional spring constant, was calculated to be 962,936 in-lb. Utilizing energy methods or the simple statics approach found in Beer & Johnston, Mechanics of Materials, Sections 11.1 - 11.3, the value of critical load Pcr, was determined to be 18,518 lb.

The value for critical load based on the simplifying assumptions exceeds the operational load limit by nearly ten times. It is judged that even upon given allowances to the simplified calculations, a significant margin of safety is inherent in this set-up.

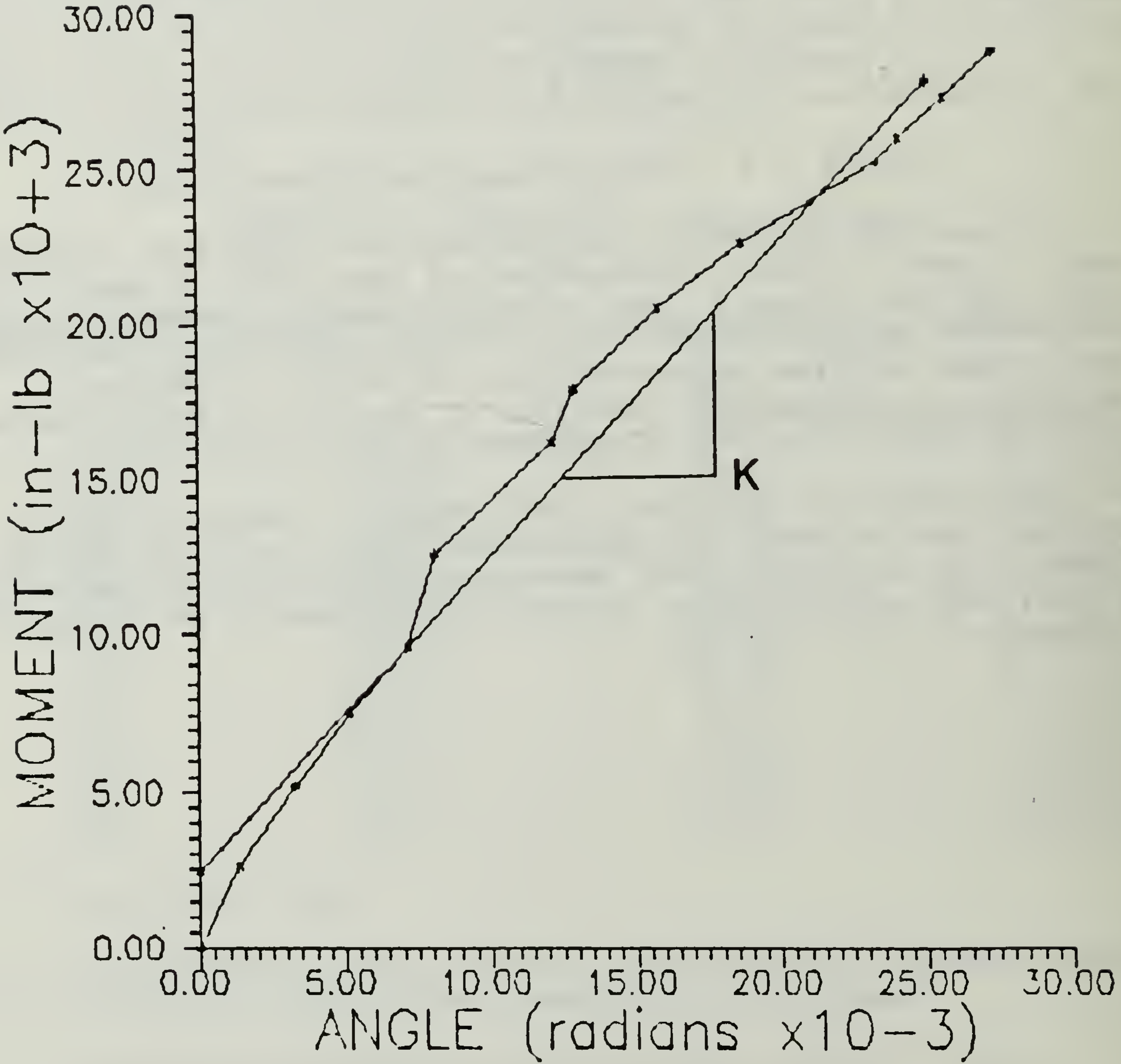


Figure 2.C Plotted Test Data

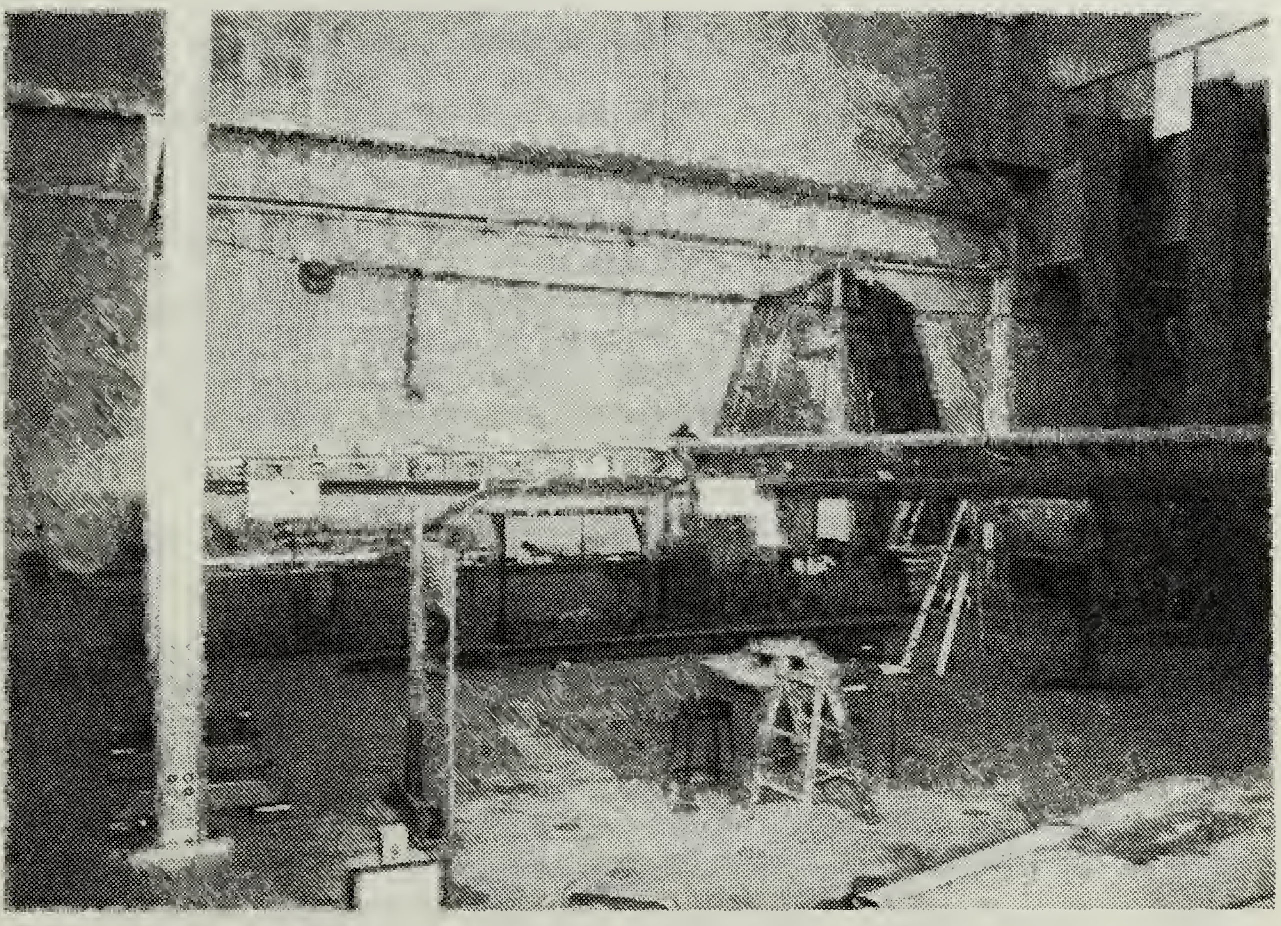


Figure 3.C   Load Frame Testing Configuration

APPENDIX D

<u>Program Listing for P2V.CAL, P2V-LOAD and ANAL.EXE</u>

```
1000    'James J.  Miller                  THESIS PROJECT
1010    'LCDR        USN
1020    '
1030    'Advisor:
1040    'Prof. Edward M. WU
1050    '
1060    '***** STRAIN GAGE CALIBRATION PROGRAM *****
1070    '
1080        '*****     VARIABLE LISTING     *****
1090        '
1100        'A - Decision variable, main menu
1110        'ADD( ) - Array containing open slots on the
                strain gage panel
1120        'ASTRN( ) - Actual DVM strain reading
1130        'A$ - Yes/No decision input varible
1140        'BDNAME$ - GPIB variable device name
1150        'B# - DVM reading converted from string
                variable
1160        'C - Counter
1170        'CF( ) - Correction factor for the gage
                connected to the DVM
1180        'C# - Counter
1190        'C% - Screen graphics flag used to determine
                a previous pass at this statement
1200        'D( ) - Dummy array used to temporarily
                store strain gage resistance updates
1210        'D( , ) - Matrix used to store all DVM
                readings
1220        'DEX - Element deformation X deflection
1230        'DEY - Element deformation Y deflection
1240        'DG# - Strain gage number being deleted
1250        'DVM% - GPIB device status variable
1260        'D$ - Today's date
1270        'D1$ - Date of last strain gage resistance
                update
1280        'E - GPIB error indicator
1290        'EMAX - Maximun strain
1300        'EMIN - Minimum strain
1310        'ESTRN( ) - Expected strain reading based on
                shunt resistance
1320        'ES1 - Intermediate strain calculation
```

```
                  variable
 1330        'EX - Strain in the X direction
 1340        'EY - Strain in the Y direction
 1350        'F$ - Analyze flag
 1360        'G( ) - Gage number associated with a DVM
 1370        'GAGE - Lead gage number for the rosette
                  being analyzed
 1380        'GF - Gage factor for the analyze rosette data
 1390        'GF( ) - Gage factor of a gage
 1400        'GLE - Element deformation angle of strain
                  deformation
 1410        'GMAX - Maximun shear strain
 1420        'GN1-GN4 - Lead gage number of rosette which
                  can be analyzed
 1430        'GXY - Gama XY, shear strain
 1440        'G$ - Single element A-3 type gage flag
 1450        'I - Counter
 1460        'IBSTA% - GPIB device error variable
 1470        'IC - Box print, interior color
 1480        'J - Counter // Box print, upper left
                  corner, row number
 1490        'K - Counter // Box print, upper left
                  corner, column number
 1500        'L - Box print, horizontal length
 1510        'LFLAG - Temporary storage for NFLAG
 1520        'M - Box print, vertical length // Integer
                  decision variable
 1530        'MSG# - Master strain gage number connected
                  to DVM1
 1540        'M$ - Input variable for analyze data of
                  rosettes
 1550        'N - Counter
 1560        'NFLAG - Flag variable used to determine if
                  the display feature had been used
 1570        'NG# - Gage number being added
 1580        'NSTOP - While loop termination flag
 1590        'N$ - Name of person currently updating
                  resistance readings
 1600        'N1$ - Name of last person to update
                  resistance readings
 1610        'PHIP - Angle of principle direction
 1620        'PGXY - Mohr's circle pixel position for shear
 1630        'PEX - Mohr's circle pixel position for
                  strain in X
 1640        'PEY - Mohr's circle pixel position for
                  strain in Y
```

```
1650        'R - Mohr's circle radius
1660        'R( ) - Resistance of a gage CAL program //
                Average of five DVM readings LOAD program
1670        'RD$ - GPIB string variable holding the DVM
                reading
1680        'RESULTS( ) - Corrected readings from the DVMs
1690        'RPG# - Gage number being replaced
1700        'RR( ) - Resistance of a gage LOAD program
1710        'R# - Strain gage resistance
1720        'S - DVM reading summary variable
1730        'SG# - Strain gage number being modified
1740        'SF - Display file gage factor
1750        'SMULT - Isotropic strain multiplier
1760        'T - Timer loop variable
1770        'TX - Timer loop variable
1780        'WRT$ - GPIB command string variable
1790        'XLOAD - Load on the wing
1800        'XIS - Mohr's circle X axis movement in
                pixels from center
1810        'XSLP - Element deformation slope of the
                horizontal lines
1820        'X1 - Element deformation pixel position
1830        'X2 - Element deformation pixel position
1840        'Y - Flag for determining if program
                previously executed this line
1850        'YSLP - Element deformation slope of the
                vertical lines
1860        'Y1 - Element deformation pixel position
1870        'Y2 - Element deformation pixel position
1880        'Z$ - Input dummy variable
1890    '
1900    REM   MAIN PROGRAM - GPIB-PC HANDLER STATEMENTS
1910    '
1920  CLEAR   ,59300!
1930  IBINIT1 = 59300!
1940  IBINIT2 = IBINIT1 + 3
1950  BLOAD "bib.m",IBINIT1
1960  CALL IBINIT1(IBFIND,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,
          IBPPC,IBBNA,IBONL,IBRSC,IBSRE,IBRSV,IBPAD,
          IBSAD,IBIST,IBDMA,IBEOS,IBTMO,IBEOT,IBRDF,
          IBWRTF)
1970  CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,
          IBWRTA,IBCMD,IBCMDA,IBRD,IBRDA,IBSTOP,IBRPP,
          IBRSP,IBDIAG,IBXTRC,IBRDI,IBWRTI,IBRDIA,
          IBWRTIA,IBSTA%,IBERR%,IBCNT%)
1980    '
```

```
1990    REM   MAIN PROGRAM - INITIAL ASSIGNMENTS,
            DIMENSIONS
2000    '
2010   KEY OFF
2020   DIM D(150), R(150), GF(150), RESULTS(12), CF(12),
          ESTRN(12), ASTRN(12), G(12), ADD(50)
2030   PRINT "~L=BACKKEY/"
2040   PRINT "~K={BACK},KEYFIX,NOESC,NOMOVE/"
2050    '
2060    REM   MAIN PROGRAM - COVER SHEET PRINT TO SCREEN
2070    '
2080   COLOR 5,0:SCREEN 0,1,1,1
2090   CLS
2100   K=5:J=5:L=70:M=15:GOSUB 3040
2110   COLOR 3
2120   LOCATE 9,39:PRINT "P2V"
2130   LOCATE 12,35:PRINT "CALIBRATION"
2140   LOCATE 15,37:PRINT "PROGRAM"
2150   COLOR 7:LOCATE 19,25:PRINT "By: LCDR J. J. Miller,
          SEPT 86"
2160   COLOR 23
2170   LOCATE 23,36:PRINT "STAND BY"
2180    '
2190    REM   MAIN PROGRAM - SELECTION PAGE PRINT TO
            SCREEN
2200    '
2210   SCREEN 0,1,3,1:COLOR 28,0:CLS:LOCATE 13,36:
          PRINT "STANDBY"
2220   SCREEN 0,1,0,1:COLOR 0,7:CLS:COLOR 4,3
2230   K=7:J=10:L=60:M=14:IC=3:GOSUB 3040
2240   COLOR 0,3:LOCATE 10,16:PRINT "Select:"
2250   LOCATE 12,22:PRINT "(1) Update strain gage
          resistances."
2260   LOCATE 13,22:PRINT "(2) Calculate strain gage
          calibration factors "
2270   LOCATE 14,26:PRINT "by a shunt resistance
          measurement."
2280   LOCATE 17,22:PRINT "(5) Add/Delete/Replace strain
          gages."
2290   LOCATE 15,22:PRINT "(3) Load the wing."
2300   LOCATE 18,22:PRINT "(6) Exit (Return to DOS)
2310   LOCATE 16,22:PRINT "(4) Analyse last recorded load
          data."
2320   SCREEN 0,1,1,1:COLOR 7,0:CLS
2330   SCREEN 0,1,0,0:COLOR 0,3
2340   LOCATE 19,11:INPUT "",A
```

```
2350  IF A=3 THEN CHAIN "P2V-LOAD"
2360  IF A<>4 GOTO 2450
2370  F$ = "Y"                   'Analyse Flag only set
2380  OPEN "DISPLAY.DAT" FOR INPUT AS #1
2390  INPUT #1, SF, XLOAD
2400  IF SF=2.09 THEN INPUT #1, GN1,GN2,GN3,GN4,GAGE
          ELSE INPUT #1, GN1,GN2,GN3,GAGE
2410  FOR I=1 TO 12:INPUT #1, RESULTS(I), G(I):NEXT I
2420  CLOSE #1
2430  GF(G(1))=SF
2440  CHAIN "P2V-LOAD",4310,ALL
2450  IF A=1! THEN GOSUB 3580 ELSE IF A=2! THEN GOSUB
          4790 ELSE IF A=5! THEN GOSUB 6940 ELSE IF A=6!
          THEN COLOR 7,0:CLS:SYSTEM ELSE COLOR 0,3:
          LOCATE 19,32:SOUND 1000,2:PRINT "Enter
          1,2,3,4,5 or 6.":GOTO 2340
2460    '
2470    REM   MAIN PROGRAM - READ PREVIOUS STRAIN GAGE
            DATA FROM FILE
2480    '
2490  OPEN "STRAIN.DAT" FOR INPUT AS #1
2500  INPUT #1,D1$,N1$
2510  FOR N=1 TO 150
2520      INPUT #1,I,R(N),GF(N)
2530      IF D(N) = 0 GOTO 2550
2540      R(N) = D(N)
2550  NEXT N
2560  CLOSE #1
2570    '
2580    REM   MAIN PROGRAM - WRITE REVISED STRAIN GAGE
            DATA TO FILE
2590    '
2600  OPEN "STRAIN.DAT" FOR OUTPUT AS #1
2610  WRITE #1,D$,N$
2620  FOR N=1 TO 150
2630      WRITE #1,N,R(N),GF(N)
2640  NEXT N
2650  CLOSE #1
2660    '
2670    REM   MAIN PROGRAM - HARD COPY SELECTION PRINT
            TO SCREEN
2680    '
2690  SCREEN 0,1,0,3
2700  COLOR 3,1:CLS:COLOR 4,7
2710  K=10:J=10:L=60:M=6:IC=7:GOSUB 3040
2720  COLOR 0,7:LOCATE 12,20:PRINT "Do you want a hard
```

```
          copy of all strain gage"
2730  LOCATE 14,20:PRINT "resistances and gage factors?
          (Y/N)"
2740  SCREEN 0,1,0,0
2750  LOCATE 14,57:INPUT "",A$
2760  IF A$="N" OR A$="n" THEN COLOR 7:CLS:GOTO 2080
2770  IF A$<>"y" AND A$<>"Y" GOTO 2750
2780  SCREEN 0,1,3,3
2790  GOSUB 3370
2800  SCREEN 0,1,0,0:COLOR 7,0:CLS
2810  GOTO 2080
2820    '
2830    REM   MAIN PROGRAM - PROGRAM RUN END
2840    '
2850  COLOR 7:CLS:END
2860   '
2870   REM   SUBPROGRAM - PRINT A ROW TO SCREEN
           (K-START, J-END, L-ROW)
2880   '
2890  FOR I=K+1 TO J-1
2900      LOCATE L,I
2910      PRINT CHR$(205)
2920  NEXT I
2930  LOCATE L,K:PRINT CHR$(204):LOCATE L,J:PRINT
          CHR$(185)
2940  RETURN
2950   '
2960   REM   SUBPROGRAM - PRINT A COLUMN TO SCREEN
           (K-START, J-END, L-COLUMN)
2970   '
2980  FOR I=K+1 TO J-1
2990      LOCATE I,L
3000      PRINT CHR$(186)
3010  NEXT I
3020  LOCATE K,L:PRINT CHR$(203):LOCATE J,L:PRINT
          CHR$(202)
3030  RETURN
3040   '
3050   REM   SUBPROGRAM - PRINT A BOX TO SCREEN
           (K,J-UPPERLEFT CORNER, L-LENGTH,
                       M-HEIGHT, IC-INTERIOR COLOR..
           DEFAULT BLACK 0)
3060   '
3070  LOCATE K,J:PRINT CHR$(201)
3080  FOR I=J+1 TO J+(L-1)
3090      LOCATE K,I
```

```
3100        PRINT CHR$(205)
3110    NEXT I
3120    LOCATE K,J+L:PRINT CHR$(187)
3130    FOR I=K+1 TO K+(M-1)
3140        LOCATE I,J
3150        PRINT CHR$(186)
3160    NEXT I
3170    LOCATE K+M,J:PRINT CHR$(200)
3180    FOR I=J+1 TO J+(L-1)
3190        LOCATE K+M,I
3200        PRINT CHR$(205)
3210    NEXT I
3220    LOCATE K+M,J+L:PRINT CHR$(188)
3230    FOR I=K+1 TO K+(M-1)
3240        LOCATE I,L+J
3250        PRINT CHR$(186)
3260    NEXT I
3270    IF IC=0 GOTO 3360
3280    COLOR IC
3290    FOR I=K+1 TO K+M-1
3300        FOR N=J+1 TO J+L-1
3310            LOCATE I,N:PRINT CHR$(219)
3320        NEXT N
3330    NEXT I
3340    COLOR 7,0
3350    IC=0
3360    RETURN
3370     '
3380     REM   SUBPROGRAM - PRINTS TO THE PRINTER A TABLE
             OF STRAIN GAGE DATA
3390     '
3400    FOR I=1 TO 79:LPRINT TAB(I);CHR$(95);:NEXT I
3410    LPRINT TAB(1);CHR$(124);TAB(79);CHR$(124)
3420    LPRINT TAB(1);CHR$(124);TAB(25);"STRAIN GAGE
            RESISTANCE SUMMARY";TAB(79);CHR$(124)
3430    LPRINT CHR$(124);:FOR I=2 TO 78:LPRINT TAB(I);
            CHR$(246);:NEXT I:LPRINT CHR$(124)
3440    LPRINT TAB(1);CHR$(124);TAB(3);"LAST ENTRY - DATE:
              ";D$;TAB(40);"NAME:  ";N$;TAB(79);CHR$(124)
3450    LPRINT CHR$(124);:FOR I=2 TO 78:LPRINT TAB(I);
            CHR$(246);:NEXT I:LPRINT CHR$(124)
3460    LPRINT TAB(1);CHR$(124);" GAGE #    OHMS     GF
            ";CHR$(124);" GAGE #    OHMS      GF  ";
            CHR$(124);" GAGE #    OHMS      GF  ";CHR$(124)
3470    LPRINT TAB(1);CHR$(124);:FOR I=2 TO 78:LPRINT
            TAB(I);CHR$(246);:NEXT I:LPRINT CHR$(124)
```

```
3480  FOR J=1 TO 45
3490      LPRINT TAB(1);CHR$(124);TAB(3);J;TAB(11);R(J);
              TAB(21);GF(J);TAB(27);CHR$(124);TAB(29);
              J+50;TAB(37);R(J+50);TAB(47);GF(J+50);
              TAB(53);CHR$(124);TAB(55);J+100;TAB(63);
              R(J+100);TAB(73);GF(J+100);TAB(79);CHR$(124)
3500  NEXT J
3510  LPRINT TAB(1);CHR$(124);TAB(4);"46";TAB(11);R(46);
          TAB(21);GF(46);TAB(27);CHR$(124);TAB(30);"96";
          TAB(37);R(96);TAB(47);GF(96);TAB(53);CHR$(124);
          TAB(57);"CALIBRATION GAGES";TAB(79);CHR$(124)
3520  LPRINT TAB(1);CHR$(124);TAB(4);"47";TAB(11);R(47);
          TAB(21);GF(47);TAB(27);CHR$(124);TAB(30);"97";
          TAB(37);R(97);TAB(47);GF(97);TAB(53);CHR$(124);
          TAB(55);"EA-13";TAB(63);R(147);TAB(73);GF(147);
          TAB(79);CHR$(124)
3530  LPRINT TAB(1);CHR$(124);TAB(4);"48";TAB(11);R(48);
          TAB(21);GF(48);TAB(27);CHR$(124);TAB(30);"98";
          TAB(37);R(98);TAB(47);GF(98);TAB(53);CHR$(124);
          TAB(56);"A-3";TAB(63);R(148);TAB(73);GF(148);
          TAB(79);CHR$(124)
3540  LPRINT TAB(1);CHR$(124);TAB(4);"49";TAB(11);R(49);
          TAB(21);GF(49);TAB(27);CHR$(124);TAB(30);"99";
          TAB(37);R(99);TAB(47);GF(99);TAB(53);CHR$(124);
          TAB(55);"AR7-2";TAB(63);R(149);TAB(73);GF(149);
          TAB(79);CHR$(124)
3550  LPRINT TAB(1);CHR$(124);TAB(4);"50";TAB(11);R(50);
          TAB(21);GF(50);TAB(27);CHR$(124);TAB(29);"100";
          TAB(37);R(100);TAB(47);GF(100);TAB(53);
          CHR$(124);TAB(55);"WA-13";TAB(63);R(150);
          TAB(73);GF(150);TAB(79);CHR$(124)
3560  FOR I=1 TO 79:LPRINT TAB(I);CHR$(176);:NEXT I:
          LPRINT CHR$(244)
3570  RETURN
3580   '
3590   REM   SUBPROGRAM - UPDATE STRAIN GAGE RESISTANCES
3600   '
3610   'Name entry screen
3620  D$ = DATE$
3630  SCREEN 0,1,0,0:COLOR 7,0:CLS:COLOR 15,0
3640  COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE
          RESISTANCE MEASUREMENT"
3650  COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE
          RESISTANCE MEASUREMENT"
3660  LOCATE 5,30
3670  PRINT "Enter operator's name."
```

```
3680  COLOR 4,7:K=12:J=30:L=20:M=2:IC=7:GOSUB 3050
3690  LOCATE 13,32:COLOR 0,7
3700  INPUT "",N$
3710   '
3720   'Instruction page for reading resistances on DVM
          1 print to screen
3730  SCREEN 0,1,0,3
3740  COLOR 7,11:CLS:COLOR 4,7
3750  K=3:J=33:L=14:M=3:IC=7:GOSUB 3040
3760  COLOR 1,7:LOCATE 4,35:PRINT "RESISTANCE"
3770  LOCATE 5,35:PRINT "MEASUREMENT"
3780  COLOR 15,0:LOCATE 9,5:PRINT CHR$(219);:COLOR 5,11:
        PRINT "  ONLY";:COLOR 0:PRINT " DVM 1 will be
        used for all resistance measurements."
3790  LOCATE 11,5:COLOR 26,11:PRINT CHR$(219);:
        COLOR 0,11:PRINT "  Ensure DVM 1 is set up as
        follows:"
3800  LOCATE 13,28:PRINT "1. Power Button - ON."
3810  LOCATE 14,28:PRINT "2. Input Button - FRONT."
3820  LOCATE 16,5:COLOR 28,11:PRINT CHR$(219);:
        COLOR 0,11:PRINT "  Connect the two-wire test
        leads to the front of the meter."
3830  COLOR 15,0:LOCATE 20,29:PRINT " SPACEBAR to
        continue "
3840  SCREEN 0,1,0,0
3850  Z$ = INKEY$
3860  IF Z$ <> CHR$(32) GOTO 3850
3870   '
3880   'Input strain gage to be read page print to screen
3890  COLOR 7,0:CLS:SCREEN 0,1,0,3:CLS:COLOR 4,7
3900  K=6:J=10:L=60:M=10:IC=7:GOSUB 3040
3910  COLOR 4,7
3920  K=10:J=70:L=11:GOSUB 2860
3930  COLOR 4,0:LOCATE 1,23:PRINT "STRAIN GAGE
        RESISTANCE MEASUREMENT"
3940  COLOR 1,7
3950  LOCATE 8,11:PRINT "        When the strain gage is
        properly connected         "
3960  LOCATE 9,11:PRINT "        to DVM1, enter strain
        gage number and <CR>.        "
3970  COLOR 5,7:LOCATE 13,11:PRINT "        NOTE:
         A resistance measurement will be taken       "
3980  LOCATE 14,11:PRINT "        using DVM1 immediately
        following <CR>.          "
3990  COLOR 15,0:LOCATE 21,22:PRINT "Enter 0 to end and
        return to the menu."
```

```
4000  SCREEN 0,1,0,0
4010  COLOR 7:LOCATE 23,1:PRINT "Enter strain gage
        number:     ":LOCATE 23,28
4020  INPUT "",SG#
4030  IF SG#<>0 THEN GOTO 4140
4040  SCREEN 0,1,0,3:COLOR 1,7:CLS:LOCATE 11,5
4050  COLOR 26,7:PRINT CHR$(219);:COLOR 0,7:PRINT "
        Ensure DVM 1 is returned to the following:"
4060  LOCATE 13,28:PRINT "1.  Power Button - cycle OFF
        then ON."
4070  LOCATE 14,28:PRINT "2.  Input Button - REAR."
4080  LOCATE 15,28:PRINT "3.  Remove the two wire test
        leads."
4090  COLOR 15,0:LOCATE 20,29:PRINT " SPACEBAR to
        continue "
4100  SCREEN 0,1,0,0
4110  Z$ = INKEY$
4120  IF Z$ <> CHR$(32) GOTO 4110
4130  SCREEN 0,1,0,0:COLOR 28,0:CLS:LOCATE 13,36:
        PRINT "STANDBY":COLOR 7:RETURN
4140  SCREEN 0,1,0,0:CLS
4150  COLOR 28,0:CLS:LOCATE 13,36:PRINT "STAND BY"
4160  GOSUB 4350
4170   '
4180   'Display resistance measurement page print to
         screen
4190  CLS
4200  COLOR 3:K=11:J=10:L=60:M=4:GOSUB 3040
4210  K=11:J=15:L=40:GOSUB 2960
4220  COLOR 7:LOCATE 13,15:PRINT "STRAIN GAGE ";SG#
4230  LOCATE 13,45:PRINT "RESISTANCE = ";R#;CHR$(234)
4240  LOCATE 20,10:PRINT "Enter:  (Y)-Measurement is
        acceptable. (approx. 118.5-123.5 ";CHR$(234);")"
4250  LOCATE 21,10:PRINT "        (N)-Cancel the reading."
4260  LOCATE 23,1:COLOR 4:INPUT "NOTE:  A (Y) entry will
        file the measurement";A$
4270  IF A$="N" OR A$="n" THEN COLOR 7,0:CLS:GOTO 3880
4280  IF A$<>"Y" AND A$<>"y" THEN PRINT "Enter Y or N.":
        GOTO 4260
4290  D(SG#)=R#
4300  SCREEN 0,1,2,2:COLOR 9:CLS
4310  K=11:J=29:L=23:M=4:GOSUB 3040
4320  COLOR 15:LOCATE 13,34:PRINT "DATA RECORDED"
4330  FOR I=1 TO 100: J=J+I:NEXT I    'Program delay
4340  GOTO 3880
4350   '
```

```
4360   REM   SUBPROGRAM - READ RESISTANCE FROM DVM1
4370   '
4380  BDNAME$ = "DVM1"
4390  CALL IBFIND (BDNAME$,DVM%)
4400  IF DVM% < 0 THEN GOSUB 4590
4410  CALL IBCLR (DVM%)
4420  IF IBSTA% < 0 THEN GOSUB 4700
4430  WRT$ = "F3R0"
4440  CALL IBWRT (DVM%,WRT$)
4450  IF IBSTA% < 0 THEN GOSUB 4700
4460  J=0:FOR I=1 TO 500:J=J+I:NEXT I 'Program delay
4470  RD$ = SPACE$(16)
4480  CALL IBRD (DVM%,RD$)
4490  IF IBSTA% < 0 THEN GOSUB 4700
4500  R#=VAL(RD$)
4510  RETURN
4520   '
4530   REM   SUBPROGRAM - GPIB-PC ERROR STATEMENTS
4540   '
4550   'A routine at this location would notify
4560   'you that the IBFIND call failed, and
4570   'refer you to the handler software
4580   'configuration procedures.
4590  PRINT "IBFIND ERROR" : PRINT "E= ";E: END
4600   '
4610   'An error checking routine at this
4620   'location would, among other things,
4630   'check IBERR to determine the exact
4640   'cause of the error condition and then
4650   'take action appropriate to the
4660   'application.  For errors during data
4670   'transfers, IBCNT may be examined to
4680   'determine the actual number of bytes
4690   'transferred.
4700  PRINT "GPIB ERROR" : PRINT "E=";E: END
4710   '
4720   'A routine at this location would analyze
4730   'the fault code returned in the DVM's
4740   'status byte and take appropriate action.
4750  PRINT "DVM ERROR" : PRINT "E= ";E: END
4760   '
4770  END
4780   '
4790   REM   SUBPROGRAM - CALCULATE STRAIN GAGE
           CALIBRATION DATA
4800   '
```

```
4810  SCREEN ,,2,3
4820   'Print to screen CALIBRATION cover page
4830  COLOR 0,1:CLS
4840  COLOR 1,7
4850  K=10:J=26:L=28:M=6:IC=7:GOSUB 3040
4860  COLOR 4,7:LOCATE 11,32:PRINT "CORRECTION FACTOR"
4870  LOCATE 13,35:PRINT "CALCULATION"
4880  LOCATE 15,37:PRINT "PROGRAM"
4890  COLOR 31,1:LOCATE 20,37:PRINT "STAND BY"
4900   '
4910   'Construct the table of strain gage calibration
           data
4920  SCREEN 0,1,0,2:COLOR 3,0:CLS
4930  K=1:J=2:L=77:M=20:IC=0:GOSUB 3040
4940  K=2:J=79:L=3:GOSUB 2870
4950  L=5:GOSUB 2870
4960  K=3:J=21:L=12:GOSUB 2960
4970  L=21:GOSUB 2960
4980  L=30:GOSUB 2960
4990  L=42:GOSUB 2960
5000  L=55:GOSUB 2960
5010  L=66:GOSUB 2960
5020  LOCATE 5,12:PRINT CHR$(206)
5030  LOCATE 5,21:PRINT CHR$(206)
5040  LOCATE 5,30:PRINT CHR$(206)
5050  LOCATE 5,42:PRINT CHR$(206)
5060  LOCATE 5,55:PRINT CHR$(206)
5070  LOCATE 5,66:PRINT CHR$(206)
5080  COLOR 15:LOCATE 2,19:PRINT "STRAIN GAGE
          CALIBRATION DATA (strain-";CHR$(230);" in/in)"
5090  COLOR 11:LOCATE 4,5:PRINT "METER":LOCATE 4,15:
          PRINT "GAGE":LOCATE 4,24:PRINT "G.F."
5100  LOCATE 4,36:PRINT CHR$(234):LOCATE 4,46:
          PRINT CHR$(238);"(expt)"
5110  LOCATE 4,58:PRINT CHR$(238);"(act)":LOCATE 4,71:
          PRINT "C.F."
5120  COLOR 9:N=1
5130  FOR J=6 TO 18 STEP 4
5140      LOCATE J,5:PRINT "DVM ";:PRINT USING "##";N
5150      LOCATE J+1,5:PRINT "DVM ";:PRINT USING "##";N+1
5160      LOCATE J+2,5:PRINT "DVM ";:PRINT USING "##";N+2
5170      N=N+3
5180  NEXT J
5190   '
5200   'Read the strain gage resistance data and gage
           factors from "STRAIN.DAT"
```

```
5210  OPEN "STRAIN.DAT" FOR INPUT AS #1
5220  INPUT #1,D1$,N1$
5230  FOR N=1 TO 150
5240      INPUT #1,I,R(I),GF(I)
5250  NEXT N
5260  CLOSE #1
5270   '
5280   'Prompt for strain gages connected to the
          respective DVMs then print the
5290   'data in the sppropriate location in the
          calibration data table
5300  SCREEN 0,1,2,2
5310  COLOR 7,0:CLS
5320  SCREEN 0,1,0,0:Y=0
5330  FOR N=1 TO 12
5340      COLOR 0,0:LOCATE 22,10:PRINT "

                 "
5350      COLOR 15:LOCATE 23,21:PRINT "Enter strain gage
              # connected to DVM ";N
5360      M=0
5370      IF N>3 THEN M=1
5380      IF N>6 THEN M=2
5390      IF N>9 THEN M=3
5400      COLOR 7:LOCATE 5+N+M,15:PRINT CHR$(219);
              CHR$(219);CHR$(219)
5410      LOCATE 5+N+M,15:COLOR 0,7:INPUT "",SG#
5420      IF SG#<1 OR SG#>146 THEN SOUND 1000,18:
              LOCATE 22,10:COLOR 31,0:PRINT "STRAIN GAGE
              ";SG#;" IS INOPERATIVE OR NOT INSTALLED.
              SELECT ANOTHER.":COLOR 15,0:GOTO 5400
5430      IF R(SG#)=0 THEN SOUND 1000,18:LOCATE 22,10:
              COLOR 31,0:PRINT "STRAIN GAGE ";SG#;
              " IS INOPERATIVE OR NOT INSTALLED. SELECT
              ANOTHER.":COLOR 15,0:GOTO 5400
5440      G(N)=SG#
5450      LOCATE 5+N+M,15:COLOR 7,0:PRINT USING "###";SG#
5460      LOCATE 5+N+M,24:PRINT USING "#.##";GF(SG#)
5470      LOCATE 5+N+M,33:PRINT USING "###.###";R(SG#)
5480      ESTRN(N)=(R(SG#)/(GF(SG#)*(59872.5+R(SG#)))*
              1000000!)
5490      IF N=1 THEN MSG#=SG#
5500      LOCATE 5+M+N,45:PRINT USING "####.###";
              ESTRN(N):IF Y=1 GOTO 5530
5510  NEXT N
5520   '
```

```
5530  'Check to see if there are any changes
5540  COLOR 4,0:LOCATE 23,15:INPUT "                           Any
          changes? (Y/N)                              ",A$
5550  IF A$ = "y" OR A$ = "Y" THEN Y=1:LOCATE 23,25:
          PRINT "  Which DVM will be changed?
                   ":LOCATE 23,56:INPUT "",N:IF Y=1 AND
          N>=1 AND N<=12 GOTO 5340 ELSE SOUND 100,3:
          GOTO 5550
5560  IF A$ <> "N" AND A$ <> "n" GOTO 5540
5570  COLOR 7,0:LOCATE 23,15:PRINT "
          STAND BY                                    "
5580  '
5590  'Print to screen the directions for hooking up
          the calibration shunt
5600  'resistor to DVM 1 which is the master for this
          experiment
5610  SCREEN 0,1,2,0:CLS
5620  COLOR 14,1
5630  K=1:J=28:L=25:M=6:IC=1:GOSUB 3040
5640  COLOR 7,1:LOCATE 2,35:PRINT "STRAIN GAGE"
5650  LOCATE 4,35:PRINT "CALIBRATION"
5660  LOCATE 6,37:COLOR 12,1:PRINT "MASTER"
5670  LOCATE 9,5
5680  COLOR 7,0:PRINT CHR$(219);"  The strain gage
          connected to DVM 1 will be the master for this
          run.";
5690  LOCATE 11,5:COLOR 25,0:PRINT CHR$(219);:COLOR 11,0
5700  PRINT "  Balance the Wheatstone bridge on DVM 1.";:
          COLOR 15,0:PRINT " Hit  SPACEBAR when balanced."
5710  SCREEN 0,1,2,2
5720  Z$ = INKEY$
5730  IF Z$ <> CHR$(32) GOTO 5720
5740  LOCATE 11,5:COLOR 9,0:PRINT CHR$(219)
5750  LOCATE 11,47:COLOR 7,0:PRINT "
                  "
5760  BDNAME$ = "DVM1"
5770  GOSUB 6720
5780  COLOR 26,0:LOCATE 13,5:PRINT CHR$(219);
5790  COLOR 15,0:PRINT "  Place the calibration shunt
          resistor across the strain gage leads ";
5800  LOCATE 14,8:PRINT "connected to DVM 1.";:
          COLOR 15,0:PRINT "  Hit SPACEBAR to continue."
5810  Z$ = INKEY$
5820  IF Z$ <> CHR$(32) GOTO 5810
5830  LOCATE 13,5:COLOR 10,0:PRINT CHR$(219)
5840  LOCATE 14,29:COLOR 7,0:PRINT "
```

```
                    "
5850  LOCATE 16,5:COLOR 28,0:PRINT CHR$(219);:COLOR 14,0:
          PRINT "  Adjust the Wheatstone Bridge power
          supply so that the reading on DVM 1";
5860  LOCATE 17,8:PRINT "is as close as possible to the
          ";CHR$(238);"(expt) of:";
5870  COLOR 0,15:LOCATE 18,36:PRINT CHR$(32);"-";:
          PRINT USING "#.###";ESTRN(1)/1000;:PRINT
          CHR$(32)
5880  COLOR 7,0:LOCATE 20,5:PRINT CHR$(219);"  Once the
          voltage source is set, do not change the
          voltage for";
5890  LOCATE 21,8:PRINT "remainder of this session."
5900  COLOR 3,0:LOCATE 23,19:PRINT "When the voltage is
          adjusted, <CR> to continue."
5910  Z$ = INKEY$
5920  IF Z$ <> CHR$(13) GOTO 5910
5930  COLOR 7,0:CLS
5940   '
5950   'Return to the calibration table and take the
           calibration shunt reading
5960   'for the other 11 strain gages
5970  SCREEN 0,1,0,0
5980  LOCATE 23,20:PRINT "                STAND BY
                          "
5990  GOSUB 6860
6000  ASTRN(1) = VAL(RD$)*(-1000000!)
6010  LOCATE 6,58:PRINT USING "####.#";ASTRN(1)
6020  CF(1) = ESTRN(1)/ASTRN(1)
6030  LOCATE 6,69:COLOR 13,0:PRINT USING "#.######";
          CF(1):COLOR 7,0
6040  Y=0!
6050  FOR N=2 TO 12
6060      LOCATE 23,10:PRINT "Balance the bridge
              connected to DVM ";N;"  SPACEBAR to
              continue."
6070      Z$ = INKEY$
6080      IF Z$ <> CHR$(32) GOTO 6070
6090      LOCATE 23,10:PRINT "
              STAND BY                                 "
6100      IF N=2 THEN BDNAME$ = "DVM2":GOSUB 6720
6110      IF N=3 THEN BDNAME$ = "DVM3":GOSUB 6720
6120      IF N=4 THEN BDNAME$ = "DVM4":GOSUB 6720
6130      IF N=5 THEN BDNAME$ = "DVM5":GOSUB 6720
6140      IF N=6 THEN BDNAME$ = "DVM6":GOSUB 6720
6150      IF N=7 THEN BDNAME$ = "DVM7":GOSUB 6720
```

```
6160       IF N=8 THEN BDNAME$ = "DVM8":GOSUB 6720
6170       IF N=9 THEN BDNAME$ = "DVM9":GOSUB 6720
6180       IF N=10 THEN BDNAME$ = "DVM10":GOSUB 6720
6190       IF N=11 THEN BDNAME$ = "DVM11":GOSUB 6720
6200       IF N=12 THEN BDNAME$ = "DVM12":GOSUB 6720
6210       LOCATE 23,3:PRINT "Place the shunt resistor
               across the leads to DVM ";N;"  <CR> to
               continue."
6220       Z$ = INKEY$
6230       IF Z$ <> CHR$(13) GOTO 6220
6240       LOCATE 23,3:PRINT "
                   STAND BY
                    "
6250       GOSUB 6860
6260       ASTRN(N) = VAL(RD$)*(-1000000!)
6270       CF(N) = ESTRN(N)/ASTRN(N)
6280       M=0
6290       IF N>3 THEN M=1
6300       IF N>6 THEN M=2
6310       IF N>9 THEN M=3
6320       LOCATE 5+N+M,58:PRINT USING "####.#";ASTRN(N)
6330       LOCATE 5+N+M,69:COLOR 13,0:PRINT USING
               "#.######";CF(N)
6340       IF Y=1! GOTO 6370
6350       COLOR 7,0
6360   NEXT N
6370   COLOR 4,0:LOCATE 23,13:INPUT "      Want to
           recalibrate any gages? (Y/N)
              ",A$
6380   LOCATE 23,1:PRINT "
                                                    "
6390   IF A$ = "y" OR A$ = "Y" THEN Y=1:LOCATE 23,12:
           PRINT "      Which DVM has the gage to be
           recalibrated?  ":LOCATE 23,66:INPUT "",N:
           IF Y=1 AND N>=2 AND N<=12 THEN COLOR 7:GOTO 6060
6400   IF N=1 AND Y=1 THEN LOCATE 23,25:PRINT "Since DVM1
           was the master, you must start again.
           SPACEBAR to continue.":INPUT "",Z$:IF
           Z$<>CHR$(32) GOTO 6400:GOTO 2080
6410   IF Y=1 AND (N<1 OR N>12) THEN SOUND 1000,2:GOTO 6390
6420    '
6430    'Constructs an output file "CALIBRAT.DAT" which
            contains the calibration
6440    'data:  DVM #, Strain gage # and Calibration factor
6450   OPEN "CALIBRAT.DAT" FOR OUTPUT AS #2
6460   FOR N=1 TO 12
```

```
6470     WRITE #2,N,G(N),CF(N)
6480  NEXT N
6490  CLOSE #2
6500   '
6510   'Machine language routine that does a PrtSc
6520  LOCATE 23,10:COLOR 18,0:PRINT "
         HARDCOPY IN PROGRESS
            "
6530  D$=DATE$
6540  LPRINT TAB(36);D$
6550  DEFINT A: DIM ARRAY (3)
6560  DATA &HCD55            :REM 55H Push BP
6570  DATA &H5D05            :REM CD05H INT 5
6580  :REM 5DH POP BP
6590  DATA &H90CB            :REM 90H NOP
6600  FOR I=1 TO 3: READ ARRAY(I): NEXT I
6610  SUBRT = VARPTR(ARRAY(1)): CALL SUBRT
6620   '
6630   'Return to the main menu
6640  LPRINT CHR$(27)+"E"
6650  LOCATE 23,10:COLOR 15,0:PRINT "Remove the
         calibration shunt resistor.";:COLOR 31:
         PRINT " SPACEBAR TO CONTINUE."
6660  Z$ = INKEY$
6670  IF Z$ <> CHR$(32) GOTO 6660
6680  GOTO 2080
6690   '
6700   'Subprogram sets meter REMOTE, clears it, sets
          function and range then
6710   'turns on the OFFSET
6720  CALL IBFIND (BDNAME$,DVM%)
6730  IF DVM% < 0 THEN GOSUB 4590
6740  CALL IBCLR (DVM%)
6750  IF IBSTA% < 0 THEN GOSUB 4700
6760  WRT$ = "F1R0"
6770  CALL IBWRT (DVM%,WRT$)
6780  IF IBSTA% < 0 THEN GOSUB 4700
6790  J=O:FOR I=1 TO 500:J=J+I:NEXT I   'Program delay
6800  WRT$ = "B1"
6810  CALL IBWRT (DVM%,WRT$)
6820  IF IBSTA% < 0 THEN GOSUB 4700
6830  RETURN
6840   '
6850   'Subprogram takes meter reading and turns OFFSET
          off
6860  RD$ = SPACE$(20)
```

```
6870  CALL IBRD (DVM%,RD$)
6880  IF IBSTA% < 0 THEN GOSUB 4700
6890  WRT$ = "B0"
6900  CALL IBWRT (DVM%,WRT$)
6910  IF IBSTA% < 0 THEN GOSUB 4700
6920  RETURN
6930   '
6940   REM   SUBROUTINE - ADD/DELETE/REPLACE STRAIN GAGES
6950   '
6960   'Construct option box
6970  SCREEN 0,1,0,3:COLOR 7,0:CLS
6980  COLOR 2,7:K=8:J=25:L=32:M=9:IC=7:GOSUB 3040
6990  COLOR 0,7:LOCATE 10,27:PRINT "Make a selection:"
7000  LOCATE 12,32:PRINT "1.  ADD strain gage"
7010  LOCATE 13,32:PRINT "2.  DELETE strain gage"
7020  LOCATE 14,32:PRINT "3.  REPLACE strain gage"
7030  LOCATE 15,32:PRINT "4.  Return to main menu"
7040   '
7050   'Read in all stored strain gage data
7060  OPEN "STRAIN.DAT" FOR INPUT AS #1
7070  INPUT #1,D1$,N$
7080  FOR N=1 TO 150
7090      INPUT #1,I,R(I),GF(I)
7100  NEXT N
7110  CLOSE #1
7120   '
7130   'Make selection
7140  SCREEN 0,1,0,0
7150  LOCATE 16,26:INPUT "",A
7160  IF A=1 THEN GOSUB 7300 ELSE IF A=2 THEN GOSUB 7730
          ELSE IF A=3 THEN GOSUB 7810 ELSE IF A=4 GOTO
          2060 ELSE SCREEN 0,1,1,1:LOCATE 17,32:
          SOUND 1000,15:PRINT "Select 1,2,3 or 4!":
          GOTO 7150
7170   '
7180   'Write to storage all strain gage data
7190  IF D$="" THEN D$=D1$
7200  OPEN "STRAIN.DAT" FOR OUTPUT AS #1
7210  WRITE #1,D$,N$
7220  FOR N=1 TO 150
7230      WRITE #1,N,R(N),GF(N)
7240  NEXT N
7250  CLOSE #1
7260   '
7270   'Return to the selection menu
7280  COLOR 7,0:CLS:GOTO 6940
```

```
 7290    '
 7300    'ADD strain gage subroutine
 7310   SCREEN 0,1,0,3
 7320   COLOR 7,0:CLS
 7330    '
 7340    'Search for the open slots on the strain gage panel
 7350   C=0
 7360   FOR N=1 TO 150
 7370       IF GF(N) = 0 THEN C=C+1:ADD(C)=N
 7380   NEXT N
 7390    '
 7400    'Construct table of open board slots
 7410   COLOR 4,0
 7420   M=CINT(C/4)+1
 7430   K=13 - CINT(M/2)
 7440   J=26:L=28:GOSUB 3040
 7450   C#=0
 7460   COLOR 11,0
 7470   FOR N=1 TO M-1
 7480       LOCATE K+N,30:PRINT USING "###";ADD(C#+1):
                LOCATE K+N,36:PRINT USING "###";ADD(C#+2):
                LOCATE K+N,43:PRINT USING "###";ADD(C#+3):
                LOCATE K+N,49:PRINT USING "###";ADD(C#+4)
 7490       C#=C#+4
 7500   NEXT N
 7510   LOCATE K-2,27:COLOR 15,0:PRINT "STRAIN GAGE BOARD
            VACANCIES"
 7520   SCREEN 0,1,0,0
 7530   LOCATE K+M+2,21:COLOR 12,0:PRINT "Select location
            of new gage from list:                  "
 7540    '
 7550    'Select new strain gage location and verify it as
             a vacancy
 7560   LOCATE K+M+2,61:COLOR 7,0:INPUT "",NG#
 7570   FOR N=1 TO C
 7580       IF NG# = ADD(N) GOTO 7610
 7590   NEXT N
 7600   SOUND 1000,18.2:GOTO 7530
 7610    '
 7620    'Enter the new gage's resistance and gage factor
 7630   CLS:COLOR 9,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
 7640   COLOR 11,0:LOCATE 10,22:PRINT "Enter manufacture
            r's listed resistance."
 7650   COLOR 14,0:LOCATE 16,10:PRINT "NOTE:  Suggest you
            run resistance update subprogram after "
 7660   LOCATE 17,10:PRINT "completion of this subprogram."
```

```
7670  COLOR 0,7:LOCATE 13,38:INPUT "",R(NG#)
7680  COLOR 7,0:CLS
7690  COLOR 9,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7700  COLOR 11,0:LOCATE 10,21:PRINT "Enter manufacture
          r's listed gage factor."
7710  COLOR 0,7:LOCATE 13,38:INPUT "",GF(NG#)
7720  COLOR 7,0:CLS:SCREEN 0,1,0,3:RETURN
7730   '
7740   'DELETE strain gage subroutine
7750  COLOR 7,0:CLS
7760  COLOR 1,7:K=12:J=37:L=6:M=2:IC=7:GOSUB 3040
7770  COLOR 11,0:LOCATE 10,23:PRINT "Enter strain gage
          number deleted:"
7780  COLOR 0,7:LOCATE 13,39:INPUT "",DG#
7790  IF DG#<1 OR DG#>150 THEN SOUND 1000,18.2:COLOR 7:
          LOCATE 13,38:PRINT "    ":GOTO 7780
7800  SCREEN 0,1,0,3:R(DG#)=0:GF(DG#)=0:RETURN
7810   '
7820   'REPLACE strain gage subroutine
7830  COLOR 7,0:CLS
7840  COLOR 1,7:K=12:J=37:L=6:M=2:IC=7:GOSUB 3040
7850  COLOR 11,0:LOCATE 10,22:PRINT "Enter strain gage
          number replaced:"
7860  COLOR 0,7:LOCATE 13,39:INPUT "",RPG#
7870  IF RPG#<1 OR RPG#>150 THEN SOUND 1000,18.2:COLOR 7:
          LOCATE 13,38:PRINT "    ":GOTO 7860
7880  COLOR 7,0:CLS
7890  COLOR 11,0:LOCATE 10,9:PRINT "Enter replacement
          strain gage manufacturer's listed resistance:"
7900  COLOR 1,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7910  COLOR 14,0:LOCATE 16,10:PRINT "NOTE:  Suggest you
          run resistance update subprogram after "
7920  LOCATE 17,10:PRINT "completion of this subprogram."
7930  COLOR 0,7:LOCATE 13,37:INPUT "",R(RPG#)
7940  COLOR 7,0:CLS
7950  COLOR 9,7:K=12:J=35:L=10:M=2:IC=7:GOSUB 3040
7960  COLOR 11,0:LOCATE 10,21:PRINT "Enter manufacture
          r's listed gage factor."
7970  COLOR 0,7:LOCATE 13,38:INPUT "",GF(RPG#)
7980  COLOR 7,0:CLS:SCREEN 0,1,0,3:RETURN
7990  LFLAG=0
8000  OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #1
8010  WRITE #1, LFLAG
8020  CLOSE #1
8030  SYSTEM:STOP:END
```

```
1000     ' James J.  Miller                    THESIS PROJECT
1010     ' LCDR        USN
1020     '
1030     ' Advisor:
1040     ' Prof. Edward M. WU
1050     '
1060     '
1070   REM   MAIN PROGRAM - GPIB-PC HANDLER STATEMENTS
1080   '
1090  CLEAR   ,59300!
1100  IBINIT1 = 59300!
1110  IBINIT2 = IBINIT1 + 3
1120  BLOAD "bib.m",IBINIT1
1130  CALL IBINIT1(IBFIND,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,
          IBPPC,IBBNA,IBONL,IBRSC,IBSRE,IBRSV,IBPAD,
          IBSAD,IBIST,IBDMA,IBEOS,IBTMO,IBEOT,IBRDF,
          IBWRTF)
1140  CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,
          IBWRTA,IBCMD,IBCMDA,IBRD,IBRDA,IBSTOP,IBRPP,
          IBRSP,IBDIAG,IBXTRC,IBRDI,IBWRTI,IBRDIA,
          IBWRTIA,IBSTA%,IBERR%,IBCNT%)
1150   '
1160   REM   MAIN PROGRAM-COVER SHEET PRINT TO SCREEN
1170   '
1180  PRINT "~L=BACKKEY/"
1190  PRINT "~K={BACK},KEYFIX,NOESC,NOMOVE/"
1200  KEY OFF:SCREEN 1,0:COLOR 1,0
1210  DEF SEG = &HB800
1220  BLOAD "C:P2WING.DRW",0
1230  DEF SEG
1240  ON TIMER (5) GOSUB 1300
1250  TIMER ON
1260  WHILE T=0
1270      TX=1
1280  WEND
1290  TIMER OFF:GOTO 1320
1300  T=1
1310  RETURN
1320  SCREEN 2,0:SCREEN 0,1:KEY OFF
1330  SCREEN 0,1,2,2:COLOR 29,0:CLS:LOCATE 13,37:
          PRINT "STANDBY"
1340   '
1350   REM   MAIN PROGRAM-INITIAL ASSIGNMENTS,
            DIMENSIONS AND SETUP
1360   '
1370  DEFINT A
```

```
1380  DIM D(12,5),R(12),G(12),CF(12),ARRAY(3),RESULTS(12)
          ,RR(150),GF(150)
1390  OPEN "DIS-FLAG.DAT" FOR INPUT AS #3
1400  INPUT #3, NFLAG
1410  CLOSE #3
1420  OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #3
1430  LFLAG=0
1440  WRITE #3, LFLAG
1450  CLOSE #3
1460  OPEN "CALIBRAT.DAT" FOR INPUT AS #1
1470  FOR N=1 TO 12
1480      INPUT #1,M,G(N),CF(N)
1490  NEXT N
1500  CLOSE #1
1510  OPEN "STRAIN.DAT" FOR INPUT AS #2
1520  INPUT #2, D1$,N1$
1530  FOR N=1 TO 150
1540      INPUT #2,I,RR(N),GF(N)
1550  NEXT N
1560  CLOSE #2
1570  IF NFLAG=1 GOTO 1740
1580   '
1590   REM   MAIN PROGRAM-DVM CONTROL: CLEAR, FUNCTION,
          RANGE, OFFSET
1600   '
1610  BDNAME$ = "DVM1": M=1: GOSUB 3020
1620  BDNAME$ = "DVM2": M=2: GOSUB 3020
1630  BDNAME$ = "DVM3": M=3: GOSUB 3020
1640  BDNAME$ = "DVM4": M=4: GOSUB 3020
1650  BDNAME$ = "DVM5": M=5: GOSUB 3020
1660  BDNAME$ = "DVM6": M=6: GOSUB 3020
1670  BDNAME$ = "DVM7": M=7: GOSUB 3020
1680  BDNAME$ = "DVM8": M=8: GOSUB 3020
1690  BDNAME$ = "DVM9": M=9: GOSUB 3020
1700  BDNAME$ = "DVM10": M=10: GOSUB 3020
1710  BDNAME$ = "DVM11": M=11: GOSUB 3020
1720  BDNAME$ = "DVM12": M=12: GOSUB 3020
1730   '
1740   REM   MAIN PROGRAM-DVM READ
1750   '
1760  PRINT "~L=BACKKEY/"
1770  PRINT "~K={BACK},KEYFIX,NOESC,NOMOVE/"
1780  SCREEN 0,1,2,2:COLOR 20,0:CLS:LOCATE 13,37:
          PRINT "STANDBY"
1790  SCREEN 0,1,0,2
1800  COLOR 14,4:CLS:COLOR 1,7
```

```
1810  K=11:J=8:L=65:M=3:IC=7:GOSUB 3650
1820  COLOR 0,7
1830  LOCATE 12,10:PRINT "When the wing is properly
          loaded, enter load applied and <CR>."
1840  LOCATE 13,12:PRINT "NOTE:  DVM readings will be
          taken immediately after <CR>."
1850  COLOR 2,7
1860  K=16:J=36:L=10:M=2:IC=7:GOSUB 3650
1870  COLOR 7,4:LOCATE 20,18:PRINT "Enter 0 when ready
          to terminate this program."
1880  COLOR 0,7:LOCATE 17,43:PRINT "LB.":SCREEN 0,1,0,0:
          LOCATE 17,38:INPUT "",XLOAD
1890  IF XLOAD = 0 GOTO 2890
1900  FOR N=1 TO 5
1910      COLOR 10,1+N:CLS
1920      LOCATE 11,23:PRINT "The program is reading all
              twelve DVMs"
1930      COLOR 31,N+1:LOCATE 13,38:PRINT "PASS ";N
1940      COLOR 15:LOCATE 15,25:PRINT "NOTE: DVMs being
              scanned in rack."
1950      BDNAME$ = "DVM1": M=1: GOSUB 3290
1960      BDNAME$ = "DVM2": M=2: GOSUB 3290
1970      BDNAME$ = "DVM3": M=3: GOSUB 3290
1980      BDNAME$ = "DVM4": M=4: GOSUB 3290
1990      BDNAME$ = "DVM5": M=5: GOSUB 3290
2000      BDNAME$ = "DVM6": M=6: GOSUB 3290
2010      BDNAME$ = "DVM7": M=7: GOSUB 3290
2020      BDNAME$ = "DVM8": M=8: GOSUB 3290
2030      BDNAME$ = "DVM9": M=9: GOSUB 3290
2040      BDNAME$ = "DVM10": M=10: GOSUB 3290
2050      BDNAME$ = "DVM11": M=11: GOSUB 3290
2060      BDNAME$ = "DVM12": M=12: GOSUB 3290
2070  NEXT N
2080   '
2090   REM   MAIN PROGRAM-AVERAGE DVM READINGS
2100   '
2110  FOR M=1 TO 12
2120      S=0
2130      FOR N=1 TO 5
2140          S=S+D(M,N)
2150      NEXT N
2160      R(M)=S/5!
2170  NEXT M
2180   '
2190   REM   MAIN PROGRAM-PRINT DVM MEASUREMENT SUMMARY
2200   '
```

```
2210  SCREEN 0,1,0,2
2220  COLOR 7,0:CLS
2230  COLOR 9:K=2:J=14:L=52:M=20:GOSUB 3650
2240  K=14:J=66:L=6:GOSUB 3560
2250  K=14:J=66:L=4:GOSUB 3560
2260  K=4:J=22:L=22:GOSUB 3470
2270  K=4:J=22:L=32:GOSUB 3470
2280  K=4:J=22:L=44:GOSUB 3470
2290  K=4:J=22:L=55:GOSUB 3470
2300  LOCATE 6,22:PRINT CHR$(206)
2310  LOCATE 6,32:PRINT CHR$(206)
2320  LOCATE 6,44:PRINT CHR$(206)
2330  LOCATE 6,55:PRINT CHR$(206)
2340  COLOR 13:LOCATE 3,16:PRINT USING "####";XLOAD;:
          PRINT " lb LOAD MEASUREMENT SUMMARY (strain-m
          in/in)"
2350  COLOR 11:LOCATE 5,17:PRINT "DVM":LOCATE 5,25:
          PRINT "GAGE#"
2360  LOCATE 5,37:PRINT "mV":LOCATE 5,48:PRINT "C.F."
2370  LOCATE 5,60:PRINT CHR$(238)
2380  FOR N=1 TO 12
2390      M = 0
2400      IF N>3 THEN M=1
2410      IF N>6 THEN M=2
2420      IF N>9 THEN M=3
2430      COLOR 7:LOCATE 6+N+M,18:PRINT USING "##";N
2440      LOCATE 6+N+M,26:PRINT USING "###";G(N)
2450      LOCATE 6+N+M,35:PRINT USING "###.###";R(N)
2460      LOCATE 6+N+M,47:PRINT USING "#.####";CF(N)
2470      RESULTS(N) = CF(N)*R(N)
2480      COLOR 15
2490      LOCATE 6+N+M,57:PRINT USING "###.###";RESULTS(N)
2500  NEXT N
2510  IF GF(G(1))=2.04 THEN G$="A3"
2520  IF GF(G(1))<>1.95 AND GF(G(1))<>1.92 GOTO 2650
2530  M = 0:L=0:COLOR 15
2540  FOR N=1 TO 12
2550      IF N=4 THEN M=1:L=0
2560      IF N=7 THEN M=2:L=0
2570      IF N=10 THEN M=3:L=0
2580      L=L+1
2590      IF L=1 THEN RESULTS(N)=RESULTS(N)+.005*RESULTS(
              N+2)
2600      IF L=3 THEN RESULTS(N)=RESULTS(N)+.005*RESULTS(
              N-2)
2610      IF L=2 THEN RESULTS(N) = (RESULTS(N) * .995) +
```

```
            (.005 * (RESLUTS(N-1) + RESULTS(N+1)))
2620     LOCATE 6+N+M,57:PRINT USING "###.###";RESULTS(N)
2630  NEXT N
2640  LOCATE 23,6:PRINT "Strain measurement includes
          poisson ratio correction for wire gages."
2650  COLOR 26:LOCATE 12,70:PRINT "PRINT"
2660  LOCATE 13,72:PRINT "IN"
2670  LOCATE 14,69:PRINT "PROGRESS"
2680  SCREEN 0,1,0,0
2690   '
2700   REM   MAIN PROGRAM-PRINT THE DVM OUTPUT
2710   '
2720  D$=DATE$
2730  LPRINT TAB(30);D$
2740  GOSUB 3980
2750  LPRINT CHR$(13)
2760  COLOR 26:LOCATE 12,70:PRINT "     "
2770  LOCATE 13,72:PRINT "  "
2780  LOCATE 14,69:PRINT "        "
2790  COLOR 4:LOCATE 7,68:PRINT "SELECT:"
2800  LOCATE 9,69:PRINT "1) Obtain":LOCATE 10,72:
          PRINT "new load"
2810  LOCATE 11,72:PRINT "data."
2820  IF G$="A3" THEN LOCATE 12,69:PRINT "2) Exit":
          LOCATE 13,72:PRINT "program.":LOCATE 14,69:
          INPUT "",M:IF M=1 GOTO 1740 ELSE IF M=2 THEN
          CLS:CHAIN "P2V-CAL",8030 ELSE SOUND 100,3:
          GOTO 2810
2830  LOCATE 12,69:PRINT "2) Analyse":LOCATE 13,72:
          PRINT "rosette"
2840  LOCATE 14,72:PRINT "data.":LOCATE 15,69:
          PRINT "3) Exit"
2850  LOCATE 16,72:PRINT "program."
2860  LOCATE 17,69:INPUT "",M
2870  IF M=1 GOTO 1740 ELSE IF M=2 GOTO 4310 ELSE IF M=3
          THEN CHAIN "P2V-CAL",8030 ELSE SOUND 100,3:
          GOTO 2850
2880   '
2890   REM   MAIN PROGRAM-TERMINATE EXECUTION
2900   '
2910  SCREEN 0,1,0,0
2920  COLOR 7,0
2930  CLS
2940  LOCATE 12,22:SOUND 1000,2:SOUND 1500,2:SOUND 2000,2
2950  PRINT "Program run completed."
2960  CLS:CHAIN "P2V-CAL",8030
```

```
2970   '
2980  END
2990   '
3000   REM   SUBROUTINE-DVM CONTROL: CLEAR, FUNCTION,
           RANGE, OFFSET
3010   '
3020  CALL IBFIND (BDNAME$,DVM%)
3030  IF DVM% < 0 THEN E=1: GOSUB 4110
3040  CALL IBCLR (DVM%)
3050  IF IBSTA% < 0 THEN E=2: GOSUB 4160
3060  WRT$ = "F1R0"
3070  CALL IBWRT (DVM%,WRT$)
3080  IF IBSTA% < 0 THEN E=3: GOSUB 4160
3090  J=0                    'Program delay
3100  FOR I=1 TO 100         'Program delay
3110      J=J+I              'Program delay
3120  NEXT I                 'Program delay
3130  IF M<>1 GOTO 3220
3140  SCREEN 0,1,0,2:COLOR 2,1:CLS:COLOR 4,7
3150  K=12:J=11:L=60:M=3:IC=7:GOSUB 3650
3160  LOCATE 13,13:COLOR 0,7:PRINT "Balance the
          Wheatstone bridge for all strain gages, then"
3170  LOCATE 14,13:COLOR 0,7
3180  PRINT "enter SPACEBAR when ready to set the OFFSET
          for all DVMs.":SCREEN 0,1,0,0
3190  Z$ = INKEY$
3200  IF Z$ <> CHR$(32) GOTO 3190
3210  COLOR 23,1:LOCATE 20,37:PRINT "STANDBY"
3220  WRT$ = "B1"
3230  CALL IBWRT (DVM%,WRT$)
3240  IF IBSTA% < 0 THEN E=4: GOSUB 4160
3250  RETURN
3260   '
3270   REM   SUBROUTINE-READ DVM
3280   '
3290  CALL IBFIND (BDNAME$,DVM%)
3300  IF DVM% < 0 THEN E=5:GOSUB 4110
3310  WRT$ = "T3"
3320  CALL IBWRT (DVM%,WRT$)
3330  IF IBSTA% < 0 THEN E=6: GOSUB 4160
3340  CALL IBTRG (DVM%)
3350  IF IBSTA% < 0 THEN E=8: GOSUB 4160
3360  RD$ = SPACE$(16)
3370  CALL IBRD (DVM%,RD$)
3380  IF IBSTA% < 0 THEN E=12: GOSUB 4160
3390  B# = VAL(RD$) * 1000!
```

```
3400  D(M,N) = B#
3410  IF N<>5 GOTO 3450
3420  WRT$ = "T0"
3430  CALL IBWRT (DVM%,WRT$)
3440  IF IBSTA% < 0 THEN E=7: GOSUB 4160
3450  RETURN
3460   '
3470   REM   SUBPROGRAM - PRINT A COLUMN TO SCREEN
           (K-START, J-END, L-COLUMN)
3480   '
3490  FOR I=K+1 TO J-1
3500      LOCATE I,L
3510      PRINT CHR$(186)
3520  NEXT I
3530  LOCATE K,L:PRINT CHR$(203):LOCATE J,L:PRINT
          CHR$(202)
3540  RETURN
3550   '
3560   REM   SUBPROGRAM - PRINT A ROW TO SCREEN
           (K-START, J-END, L-ROW)
3570   '
3580  FOR I=K+1 TO J-1
3590      LOCATE L,I
3600      PRINT CHR$(205)
3610  NEXT I
3620  LOCATE L,K:PRINT CHR$(204):LOCATE L,J:PRINT
          CHR$(185)
3630  RETURN
3640   '
3650   REM   SUBPROGRAM - PRINT A BOX TO SCREEN
           (K,J-UPPERLEFT CORNER, L-LENGTH,
                       M-HEIGHT, IC-INTERIOR COLOR..
           DEFAULT BLACK 0)
3660   '
3670  LOCATE K,J:PRINT CHR$(201)
3680  FOR I=J+1 TO J+(L-1)
3690      LOCATE K,I
3700      PRINT CHR$(205)
3710  NEXT I
3720  LOCATE K,J+L:PRINT CHR$(187)
3730  FOR I=K+1 TO K+(M-1)
3740      LOCATE I,J
3750      PRINT CHR$(186)
3760  NEXT I
3770  LOCATE K+M,J:PRINT CHR$(200)
3780  FOR I=J+1 TO J+(L-1)
```

```
3790        LOCATE K+M,I
3800        PRINT CHR$(205)
3810    NEXT I
3820    LOCATE K+M,J+L:PRINT CHR$(188)
3830    FOR I=K+1 TO K+(M-1)
3840        LOCATE I,L+J
3850        PRINT CHR$(186)
3860    NEXT I
3870    IF IC=0 GOTO 3960
3880    COLOR IC
3890    FOR I=K+1 TO K+M-1
3900        FOR N=J+1 TO J+L-1
3910            LOCATE I,N:PRINT CHR$(219)
3920        NEXT N
3930    NEXT I
3940    COLOR 7,0
3950    IC=0
3960    RETURN
3970     '
3980     REM   SUBROUTINE-PRINT SCREEN
3990     '
4000    A=0:RESTORE
4010    DATA &HCD55                 :REM 55H Push BP
4020    DATA &H5D05                 :REM CD05H INT 5
4030    :REM 5DH POP BP
4040    DATA &H90CB                 :REM 90H NOP
4050    FOR I=1 TO 3: READ ARRAY(I): NEXT I
4060    SUBRT = VARPTR(ARRAY(1)): CALL SUBRT
4070    RETURN
4080     '
4090     REM   ERROR SUBROUTINE LOCATIONS
4100     '
4110     '       A routine at this location would notify
4120     '       you that the IBFIND call failed, and
4130     '       refer you to the handler software
4140     '       configuration procedures.
4150    PRINT "IBFIND ERROR" : PRINT "E= ";E: PRINT "DVM ";
            M: STOP
4160     '       An error checking routine at this
4170     '       location would, among other things,
4180     '       check IBERR to determine the exact
4190     '       cause of the error condition and then
4200     '       take action appropriate to the
4210     '       application.  For errors during data
4220     '       transfers, IBCNT may be examined to
4230     '       determine the actual number of bytes
```

```
4240   '       transferred.
4250  PRINT "GPIB ERROR" : PRINT "E=";E: STOP
4260   '       A routine at this location would analyze
4270   '       the fault code returned in the DVM's
4280   '       status byte and take appropriate action.
4290  PRINT "DVM ERROR" : PRINT "E= ";E:PRINT "DVM ";M:
          STOP
4300  END
4310   REM   Portion of program which does the rosette
          analysis
4320   '
4330  SCREEN 0,1,0,0:COLOR 7:CLS
4340  PRINT "~K={BACK}/"
4350  SCREEN 2
4360  KEY OFF:SCREEN 1,0:CLS
4370  COLOR 1,0
4380  IF C%=0 THEN DIM PIX#(700):C%=1
4390  DEF SEG
4400  PIX.PTR=VARPTR(PIX#(0))
4410  BLOAD "C:ROSETTE.PIX",PIX.PTR
4420  VIEW (70,39)-(250,159),,3
4430  PUT (40,5),PIX#
4440  ON TIMER(3) GOSUB 4510
4450  TIMER ON:T=0
4460  WHILE T=0
4470      SUM = 0
4480  WEND
4490  VIEW
4500  GOTO 4530
4510  T=1
4520  RETURN
4530  SCREEN 1,0:COLOR 1,0:CLS
4540  DEF SEG
4550  PIX.PTR=VARPTR(PIX#(0))
4560  BLOAD "C:ANALIZE2.PIX",PIX.PTR
4570  PUT (18,1),PIX#
4580  WHILE GF(G(1))=2.09
4590      LOCATE 15,3:PRINT USING "####";XLOAD;:
              PRINT " LB. LOAD"
4600      LOCATE 15,18:PRINT CHR$(214);CHR$(196);
              " A    B    C ";CHR$(196);CHR$(183)
4610      LOCATE 16,6:PRINT "SELECT":LOCATE 16,18:
              PRINT CHR$(186);" ";:PRINT USING "###";
              G(1);:PRINT USING "#####";G(5);:
              PRINT USING "#####";G(9);:PRINT " ";
              CHR$(186)
```

```
4620      LOCATE 17,6:PRINT "ROSETTE":LOCATE 17,18:
              PRINT CHR$(186);" ";:PRINT USING "###";
              G(2);:PRINT USING "#####";G(6);:
              PRINT USING "#####";G(10);:PRINT " ";
              CHR$(186)
4630      LOCATE 18,18:PRINT CHR$(186);" ";:PRINT USING
              "###";G(3);:PRINT USING "#####";G(7);:
              PRINT USING "#####";G(11);:PRINT " ";
              CHR$(186)
4640      LOCATE 19,18:PRINT CHR$(186);" ";:PRINT USING
              "###";G(4);:PRINT USING "#####";G(8);:
              PRINT USING "#####";G(12);:PRINT " ";
              CHR$(186)
4650      LOCATE 20,18:PRINT CHR$(211);CHR$(196);
              CHR$(196);CHR$(196);CHR$(196);CHR$(196);
              "GAGES";CHR$(196);CHR$(196);CHR$(196);
              CHR$(196);CHR$(196);CHR$(189)
4660      VIEW (5,163)-(314,187),,2
4670      LOCATE 22,7:PRINT "For rosette ENTER A,B OR C."
4680      IF F$<>"Y" THEN LOCATE 23,4:PRINT "ENTER L to
              return to Load program." ELSE LOCATE 23,4:
              PRINT "ENTER X to end."
4690      LOCATE 23,38:INPUT "",M$
4700      IF M$="X" OR M$="x" THEN CLS:SCREEN 2:SCREEN 0:
              LFLAG=0:OPEN "DIS-FLAG.DAT" FOR OUTPUT AS
              #2:WRITE #2,LFLAG:CLOSE #2:CHAIN
              "P2V-CAL",8030
4710      IF M$ = "L" OR M$ = "l" THEN CLS:GOSUB 4940
4720      IF M$="A" OR M$="a" THEN GN1=1:GN2=2:GN3=3:
              GN4=4:GAGE=G(1):GOSUB 4940
4730      IF M$="B" OR M$="b" THEN GN1=5:GN2=6:GN3=7:
              GN4=8:GAGE=G(5):GOSUB 4940
4740      IF M$="C" OR M$="c" THEN GN1=9:GN2=10:GN3=11:
              GN4=12:GAGE=G(9):GOSUB 4940
4750      SOUND 100,3:GOTO 4690
4760  WEND
4770  LOCATE 15,3:PRINT USING "####";XLOAD;:PRINT " LB.
          LOAD"
4780  LOCATE 16,18:PRINT CHR$(214);CHR$(196);" A    B
          C    D";CHR$(196);CHR$(183)
4790  LOCATE 17,5:PRINT "SELECT":LOCATE 17,18:
          PRINT CHR$(186);:PRINT USING "###";G(1);:
          PRINT USING "#####";G(4);:PRINT USING "#####";
          G(7);:PRINT USING "#####";G(10);:PRINT " ";
          CHR$(186)
4800  LOCATE 18,5:PRINT "ROSETTE":LOCATE 18,18:
```

```
          PRINT CHR$(186);:PRINT USING "###";G(2);:
          PRINT USING "#####";G(5);:PRINT USING "#####";
          G(8);:PRINT USING "#####";G(11);:PRINT " ";
          CHR$(186)
4810  LOCATE 19,18:PRINT CHR$(186);:PRINT USING "###";
          G(3);:PRINT USING "#####";G(6);:PRINT USING
          "#####";G(9);:PRINT USING "#####";G(12);:
          PRINT " ";CHR$(186)
4820  LOCATE 20,18:PRINT CHR$(211);CHR$(196);CHR$(196);
          CHR$(196);CHR$(196);CHR$(196);CHR$(196);
          CHR$(196);"GAGES";CHR$(196);CHR$(196);
          CHR$(196);CHR$(196);CHR$(196);CHR$(196);
          CHR$(196);CHR$(189)
4830  VIEW (5,163)-(314,187),,2
4840  LOCATE 22,7:PRINT "For rosette ENTER A,B,C or D."
4850  IF F$<>"Y" THEN LOCATE 23,4:PRINT "ENTER L to
          return to Load program." ELSE LOCATE 23,4:
          PRINT "ENTER X to end."
4860  LOCATE 23,38:INPUT "",M$
4870  IF M$="X" OR M$="x" THEN CLS:SCREEN 2:SCREEN 0:
          LFLAG=0:OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #2:
          WRITE #2,LFLAG:CLOSE #2:CHAIN "P2V-CAL",8030
4880  IF M$ = "L" OR M$ = "l" THEN CLS:GOSUB 4940
4890  IF M$="A" OR M$="a" THEN GN1=1:GN2=2:GN3=3:
          GAGE=G(1):GOSUB 4940
4900  IF M$="B" OR M$="b" THEN GN1=4:GN2=5:GN3=6:
          GAGE=G(4):GOSUB 4940
4910  IF M$="C" OR M$="c" THEN GN1=7:GN2=8:GN3=9:
          GAGE=G(7):GOSUB 4940
4920  IF M$="D" OR M$="d" THEN GN1=10:GN2=11:GN3=12:
          GAGE=G(10):GOSUB 4940
4930  SOUND 100,3:GOTO 4860
4940   '
4950  OPEN "DISPLAY.DAT" FOR OUTPUT AS #1
4960  WRITE #1, GF(G(1)), XLOAD
4970  IF GF(G(1)) = 2.09 THEN WRITE #1, GN1, GN2, GN3,
          GN4, GAGE ELSE WRITE #1, GN1, GN2, GN3, GAGE
4980  FOR I=1 TO 12
          WRITE #1, RESULTS(I), G(I)
4990
5000  NEXT I
5010  CLOSE #1
5020  IF M$="L" OR M$="l" THEN CLS:SCREEN 2:SCREEN 0:
          IF NFLAG=1 THEN RETURN 1000 ELSE RETURN 1740
5030  SHELL "ANALIZE.BAT"
5040  NFLAG = 1
5050  OPEN "DIS-FLAG.DAT" FOR OUTPUT AS #3
```

```
5060  WRITE #3, NFLAG
5070  CLOSE #3
5080  RETURN 4330
```

```
1000   REM   This is a compiled executable BASIC program
            which does the
1010   REM   high resolution display portion of the
            rosette analysis
1020   '
1030   'Variable declarations
1040  DIM  RESULTS(12), G(12)
1050   '
1060   'Retrieve data to be displayed from the hard disk
1070  OPEN "DISPLAY.DAT" FOR INPUT AS #1
1080  INPUT #1, GF, XLOAD
1090  IF GF=2.09 THEN INPUT #1, GN1, GN2, GN3, GN4, GAGE
          ELSE INPUT #1, GN1, GN2, GN3, GAGE
1100  FOR I=1 TO 12
1110      INPUT #1, RESULTS(I), G(I)
1120  NEXT I
1130  CLOSE #1
1140   '
1150  KEY OFF
1160   '
1170   'Calculations for the older AR-7-2 wire rosette
1180  WHILE (GF=1.92 OR GF=1.95) AND NSTOP=0
1190      EX = RESULTS(GN1):EY = RESULTS(GN3)
1200      IF GAGE<17 OR GAGE=24 OR GAGE=30 OR GAGE=33 OR
              GAGE=85 OR GAGE=38 OR GAGE=88 OR GAGE=91
              OR GAGE=41 OR GAGE=73 OR GAGE=76 THEN
              EX=RESULTS(GN3):EY=RESULTS(GN1)
1210      GXY = (2! * RESULTS(GN2)) - (EX + EY)
1220      IF GAGE=56 OR GAGE=59 OR GAGE=62 OR GAGE=50
              THEN GXY=-1! * GXY
1230      ES1 = (EX + EY)/2!
1240      GMAX = SQR((EX - EY)^2 + GXY^2)
1250      EMAX = ES1 + .5*GMAX
1260      EMIN = ES1 - .5*GMAX
1270      PHIP = (.5 + ATN(GXY/(EX - EY))) * 57.2958
1280      NSTOP=1
1290  WEND
1300  NSTOP=0
1310   '
1320   'Calculations for the new EA-13-250YA delta rosette
1330  WHILE GF=2.07 AND NSTOP=0
1340      EY=RESULTS(GN1)
1350      GXY=(RESULTS(GN3)-RESULTS(GN2))/.8660254
1360      EX=(RESULTS(GN2)+(.4330127*GXY)-(.25*EY))/.75
1370      IF GAGE=112 THEN GXY=(RESULTS(GN2)-RESULTS(GN3)
              )/.8660254:EX=(RESULTS(GN3)+(.4330127*GXY)-
```

```
              (.25*EY))/.75
1380      IF GAGE=109 THEN EY=RESULTS(GN2):GXY=(RESULTS(
              GN3)-RESULTS(GN1))/.8660254:EX=(RESULTS(
              GN1)+(.4330127*GXY)-(.25*EY))/.75
1390      ES1 = (EX + EY)/2!
1400      GMAX = SQR((EX - EY)^2 + GXY^2)
1410      EMAX = ES1 + .5*GMAX
1420      EMIN = ES1 - .5*GMAX
1430      PHIP = (.5 + ATN(GXY/(EX - EY))) * 57.2958
1440      NSTOP=1
1450  WEND
1460  NSTOP = 0
1470   '
1480   'Calculation for the new WA-13-250WF stacked
          rosette
1490  WHILE GF=2.09 AND NSTOP=0
1500      EX=RESULTS(GN2):EY=RESULTS(GN4)
1510      GXY=(RESULTS(GN3) - RESULTS(GN1)) - (EX - EY)
1520      IF GAGE=128 THEN EX=RESULTS(GN1):EY=RESULTS(
              GN3):GXY=(RESULTS(GN2)-RESULTS(GN4))-(EX-EY)
1530      IF GAGE=124 THEN EX=RESULTS(GN2):EY=RESULTS(
              GN4):GXY=(RESULTS(GN1)-RESULTS(GN3))-(EX-EY)
1540      ES1 = (EX + EY)/2!
1550      GMAX = SQR((EX - EY)^2 + GXY^2)
1560      EMAX = ES1 + .5*GMAX
1570      EMIN = ES1 - .5*GMAX
1580      PHIP = (.5 + ATN(GXY/(EX - EY))) * 57.2958
1590      NSTOP=1
1600  WEND
1610  NSTOP = 0
1620   '
1630   'Calculation for Mohr's circle radius
1640  R = .5 * SQR((EX - EY)^2 + GXY^2)
1650   '
1660   'Construct the display screen
1670  CLS:SCREEN 9:COLOR 15
1680  LINE (1,306)-(639,306)  'Screen Dividers
1690  LINE (319,0)-(319,306)
1700  LOCATE 2,14:PRINT "MOHR'S CIRCLE"
1710  LOCATE 2,52:PRINT "SURFACE DEFORMATION"
1720  COLOR 9
1730  LOCATE 23,29:PRINT CHR$(232);"p=";:PRINT USING
          "####";PHIP;:PRINT CHR$(248);
1740  LOCATE 25,56:PRINT "Gmax=";:PRINT USING "##.###";
          GMAX;
1750  LOCATE 23,41:PRINT CHR$(238);"min=";:PRINT USING
```

```
          "##.###";EMIN;
1760  LOCATE 25,41:PRINT CHR$(238);"max=";:PRINT USING
          "##.###";EMAX;
1770  LOCATE 23,56:PRINT "Gxy=";:PRINT USING "##.###";GXY;
1780  LOCATE 23,71:PRINT CHR$(238);"y=";:PRINT USING
          "##.###";EY;
1790  LOCATE 25,71:PRINT CHR$(238);"x=";:PRINT USING
          "##.###";EX;
1800  LOCATE 23,1:PRINT USING "####";XLOAD;:PRINT " LB
          LOAD"
1810  LOCATE 23,16:PRINT CHR$(238);"-m in/in"
1820  LOCATE 1,1:PRINT DATE$
1830  IF GF<>2.09 THEN LOCATE 25,1:PRINT "Gages-";:
          PRINT USING "###";G(GN1);:PRINT ",";:
          PRINT USING "###";G(GN2);:PRINT ",";:
          PRINT USING "###";G(GN3);
1840  IF GF=2.09 THEN LOCATE 25,1:PRINT "Gages-";:
          PRINT USING "###";G(GN1);:PRINT ",";:
          PRINT USING "###";G(GN2);:PRINT ",";:
          PRINT USING "###";G(GN3);:PRINT ",";:
          PRINT USING "###";G(GN4);
1850  SCALE = R/1.5151515#
1860  XIS = (ES1 * 100! / R) * -1
1870  COLOR 10
1880  LINE (5,160)-(315,160)  'X and Y axis
1890  LINE (159 + XIS,260)-(159 + XIS,43)
1900  LINE (323,160)-(635,160)
1910  LINE (479,27)-(479,260)
1920  COLOR 2
1930  LOCATE 13,1:PRINT CHR$(238)  'Axis Labels
1940  LOCATE 3,14:PRINT "Gxy/2"
1950  LOCATE 3,58:PRINT "Y"
1960  LOCATE 13,78:PRINT "X"
1970  IF ABS(EX)<.5 AND ABS(EY)<.5 AND ABS(GXY)<.5 THEN
          SMULT=2! ELSE SMULT=1!
1980  EX = SMULT * EX:EY = SMULT * EY:GXY=SMULT * GXY
1990   'Calculations for the element deformation shape
2000  DEX = 75 * (EX/2!)
2010  DEY = 61 * (EY/2!)
2020  GLE = ATN(ABS(GXY/2!))
2030  IF GXY < 0 THEN GLE = GLE * -1!
2040  YSLP = TAN(1.5707963# - GLE) * .77272727#
2050  XSLP = TAN(GLE) * .77272727#
2060  X1 = ((61! + DEY) + YSLP * (75! + DEX))/(YSLP -
          XSLP)
2070  X2 = ((61! + DEY) + YSLP * (-75! - DEX))/(YSLP -
```

```
          XSLP)
2080  Y1 = (((XSLP * YSLP) * (75! + DEX)) + (YSLP * (61!
          + DEY)))/(YSLP - XSLP)
2090  Y2 = (((XSLP * YSLP) * (-75! - DEX)) + (YSLP *
          (61! + DEY)))/(YSLP - XSLP)
2100  COLOR 7
2110  LINE (404,99)-(554,221),,B
2120  LOCATE 8,59:PRINT ".5"
2130  LOCATE 13,68:PRINT ".5"
2140  COLOR 3
2150  LOCATE 20,56:PRINT "Unit Cube"
2160  LOCATE 21,49:PRINT "Isotropic Strain Mult=";:
          PRINT USING "#";SMULT
2170  COLOR 10
2180  LINE (118,284)-(184,284)
2190  LINE (118,282)-(118,286)
2200  LINE (184,282)-(184,286)
2210  COLOR 3
2220  LOCATE 20,14:PRINT USING ".###";SCALE;:PRINT " m
          in/in"
2230  COLOR 12
2240  LINE (479+X1,160-Y1)-(479-X2,160+Y2),,,&HAAAA
2250  LINE (479-X2,160+Y2)-(479-X1,160+Y1),,,&HAAAA
2260  LINE (479-X1,160+Y1)-(479+X2,160-Y2),,,&HAAAA
2270  LINE (479+X2,160-Y2)-(479+X1,160-Y1),,,&HAAAA
2280  COLOR 7
2290   'Calculations for the Mohr's circle position
2300  CIRCLE (159,160),100,,,,.81
2310  IF SMULT=2 THEN EX = EX/2!:EY = EY/2!:GXY = GXY/2!
2320  PEY = ((EY * 66!) / SCALE)
2330  PEX = ((EX * 66!) / SCALE)
2340  PGXY = (((GXY/2!) * 53.5) / SCALE)
2350  COLOR 12
2360  LINE (159 + XIS + PEY,160)-(159 + XIS + PEY,160 -
          PGXY)
2370  LINE -(159 + XIS + PEX,160 + PGXY)
2380  LINE -(159 + XIS + PEX,160)
2390  COLOR 10
2400  LINE (159+XIS+66,158)-(159+XIS+66,162) 'Scale Marker
2410  LINE (157+XIS,107)-(161+XIS,107)
2420  COLOR 4:LOCATE 1,23:PRINT "(Shift/PrtSc) for
          print, SPACEBAR to return."
2430  Z$ = INKEY$
2440  IF Z$ <> CHR$(32) GOTO 2430
2450  LPRINT CHR$(13)
2460  END
```

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